Convening the System to Build Utility-Scale Geothermal Networks

NSF

MASSACHUSETTS CLEAN ENERGY CENTER®

Barr Foundation

Putnam Foundation

Welcome

- Diverse knowledge in room
- Simultaneous translation

- Developing shared language
- Pilot site criteria

Dedication photos : info@HEETma.org

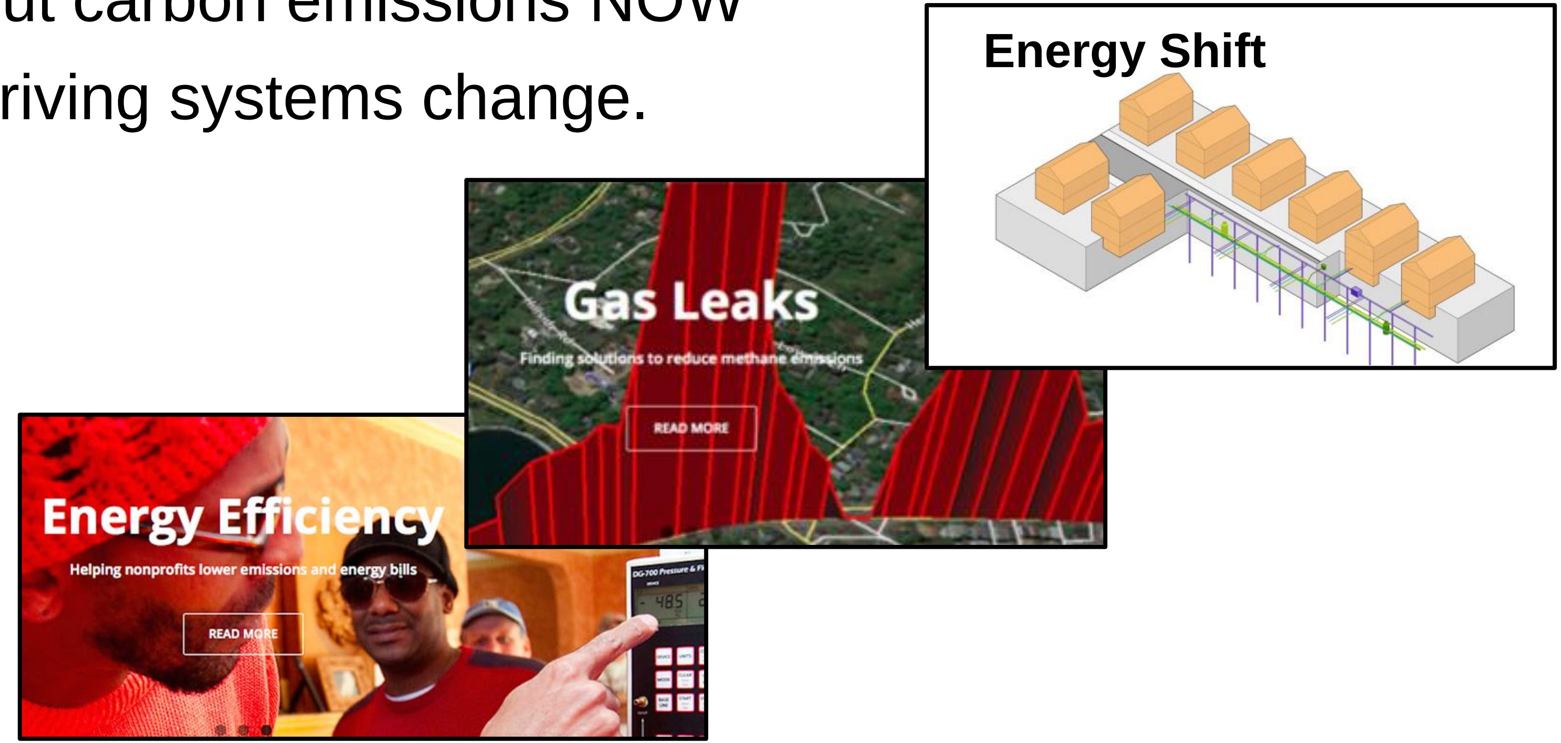
Goals of the Day

- Learn from each other
- Begin to create shared language
- Identify key questions & next steps:
    - Pilot site selection criteria
    - Pilot site success criteria

HEET: Independent

To cut carbon emissions NOW

by driving systems change.



Energy Shift

Gas Leaks

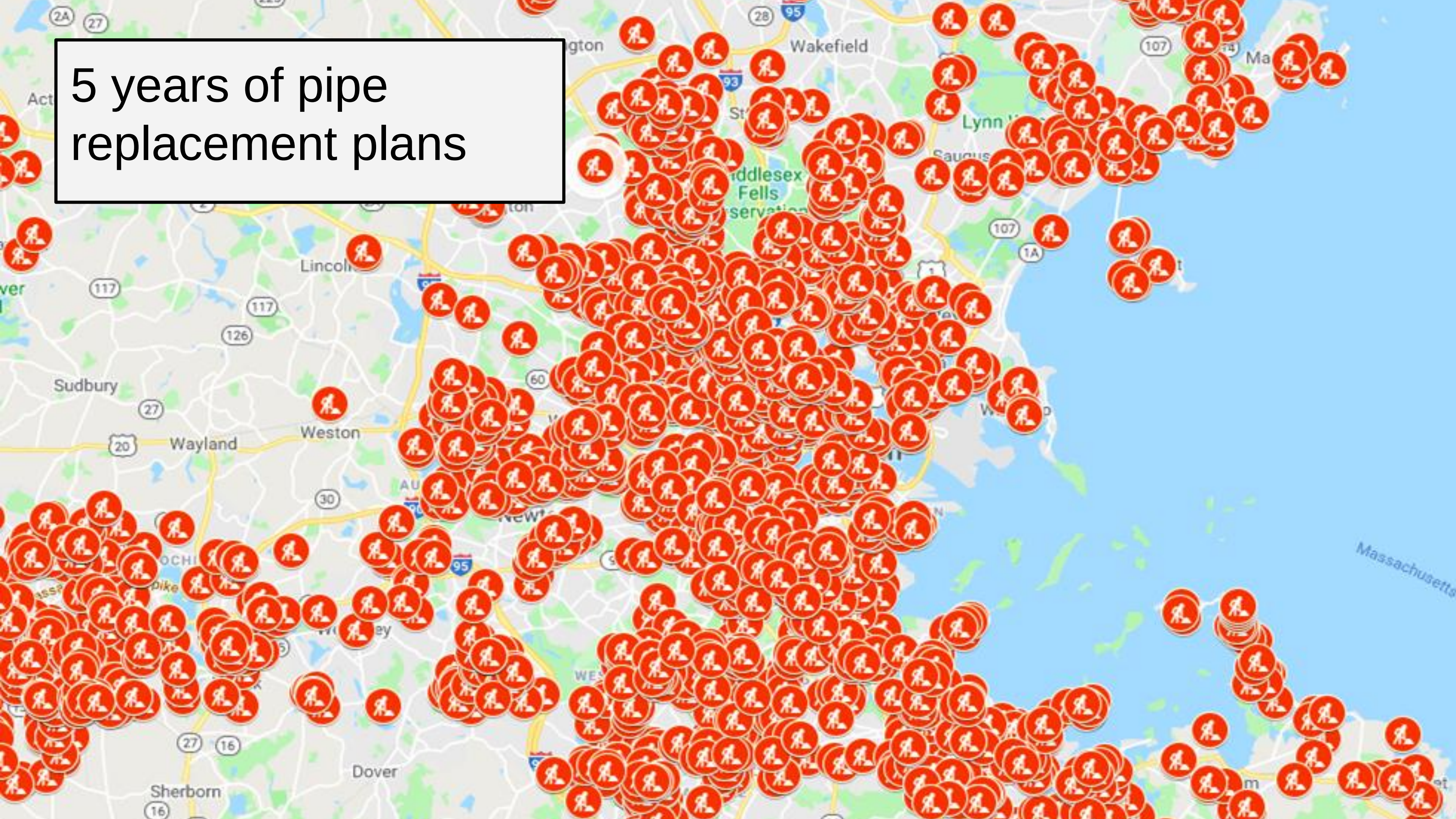
Finding solutions to reduce methane emissions

Energy Efficiency

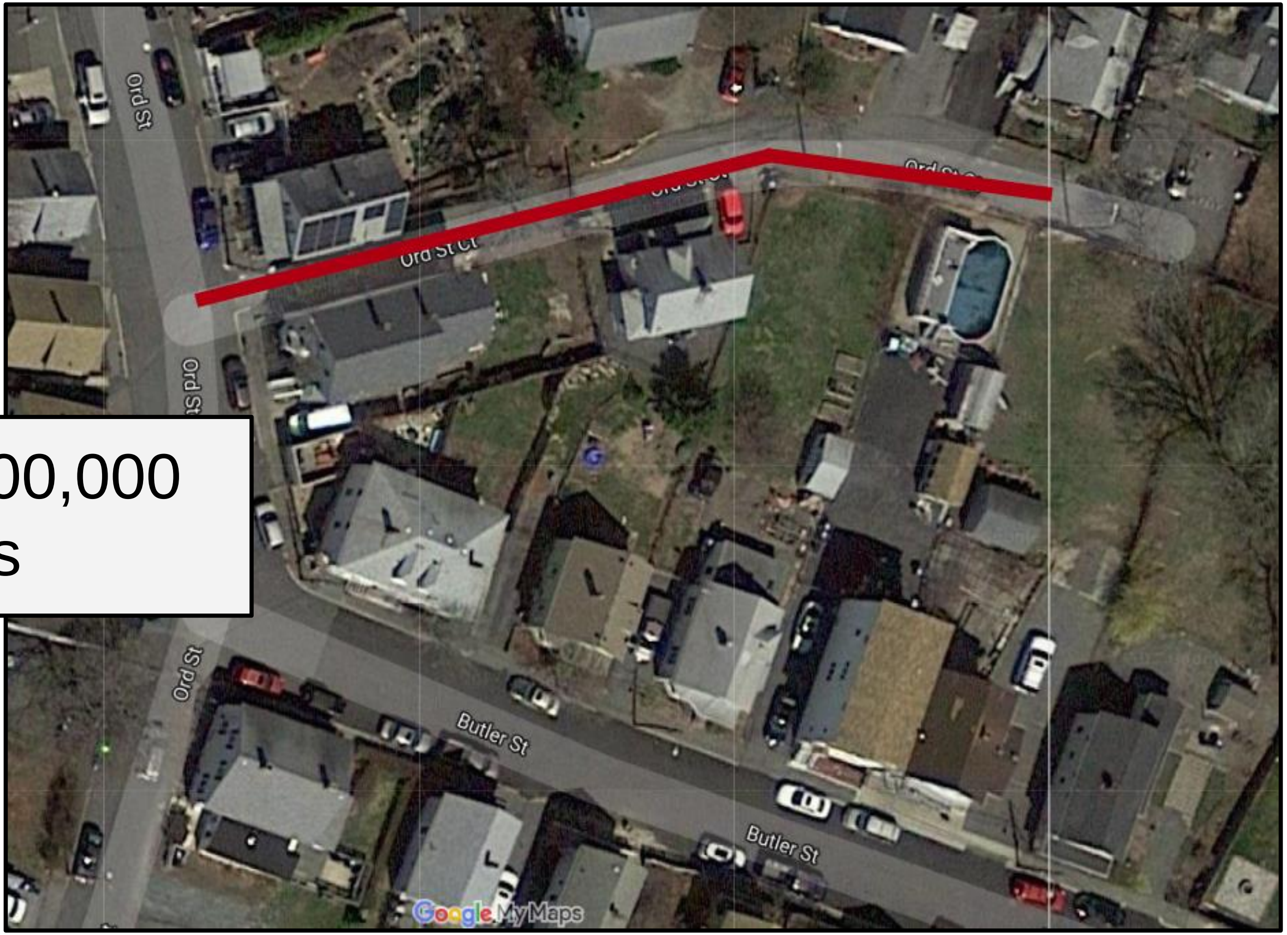
Helping nonprofits lower emissions and energy bills

MA Gas Pipe Replacement

- >25% gas mains leakprone
- ~20 year plan
- $9 billion cost
- 40 years depreciation
- Emission mandates: 80% by 2050



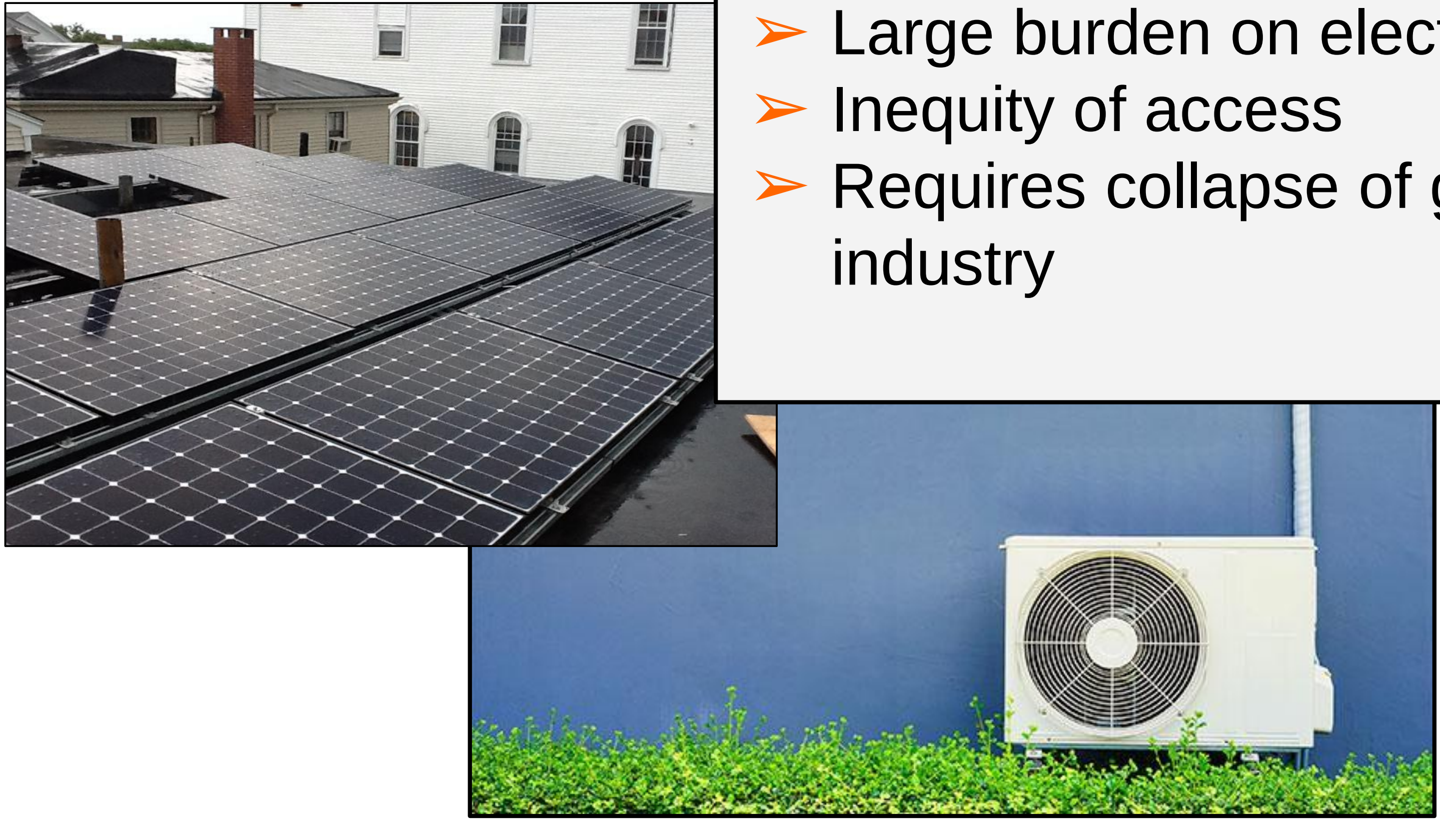
5 years of pipe replacement plans



Cost: $100,000

4 Homes

- Don’t work everywhere
- Large burden on electric grid
- Inequity of access
- Requires collapse of gas industry



Heat Pumps

Air Source Heat Pumps

They are all around us today.

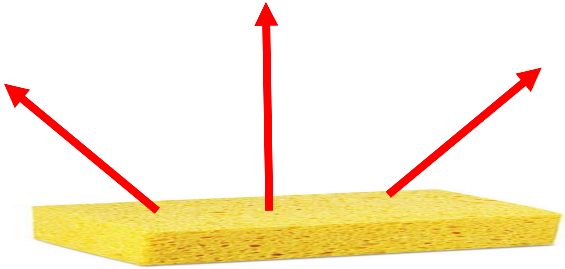
Heat pumps aren’t new technology.

They can be trusted

©Erin

How they work

They contain a fluid that works like a sponge for heat.



When they expand, they absorb heat.

When compressed they “reject” heat.

Efficient

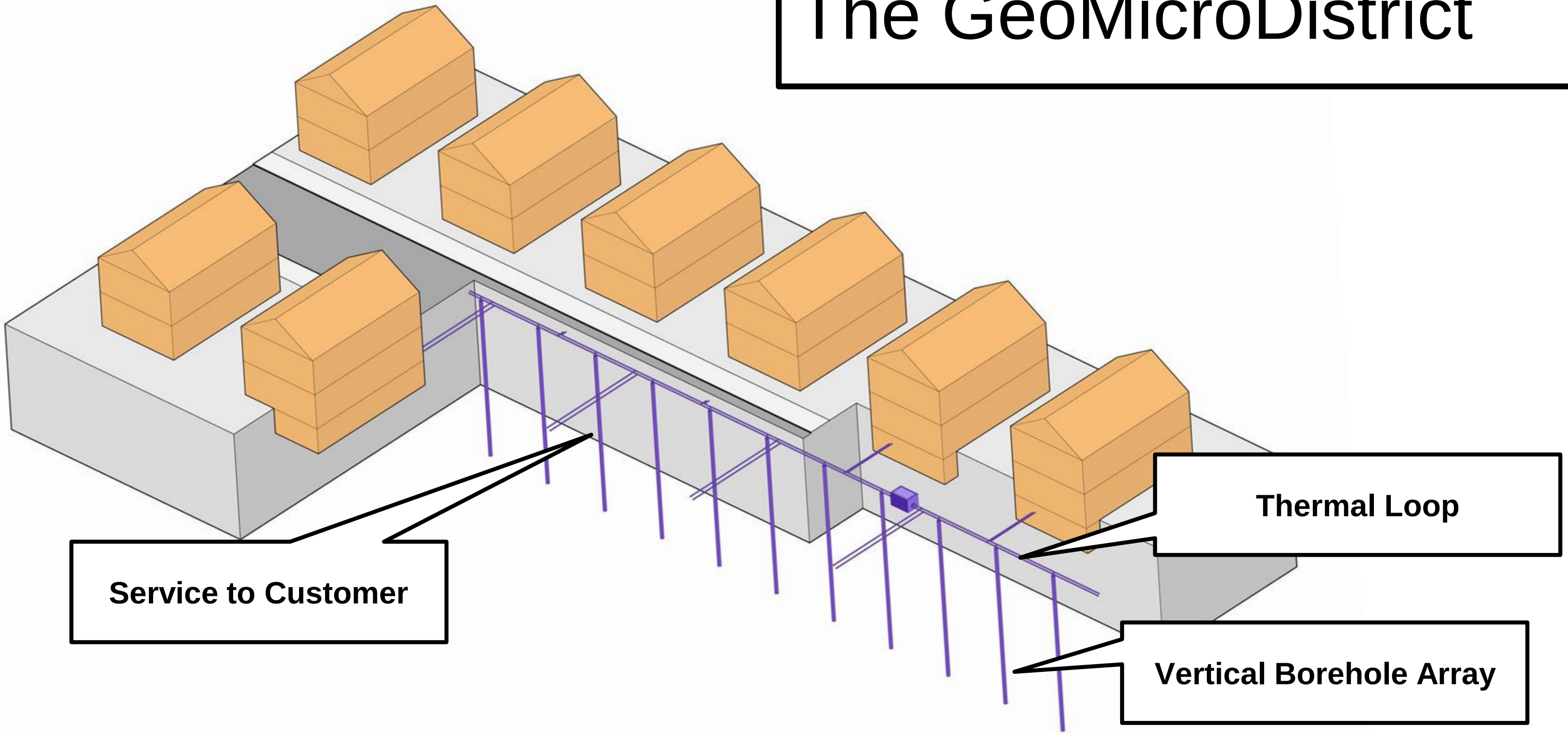
A boiler **creates** heat through fire.

A heat pump **moves** existing energy.

Design Principles

- Safe
- Renewable & resilient & reliable
- Low cost for consumers
- Workers keep their jobs
- Minimal legislative & regulatory change
- Scalable & flexible

The GeoMicroDistrict

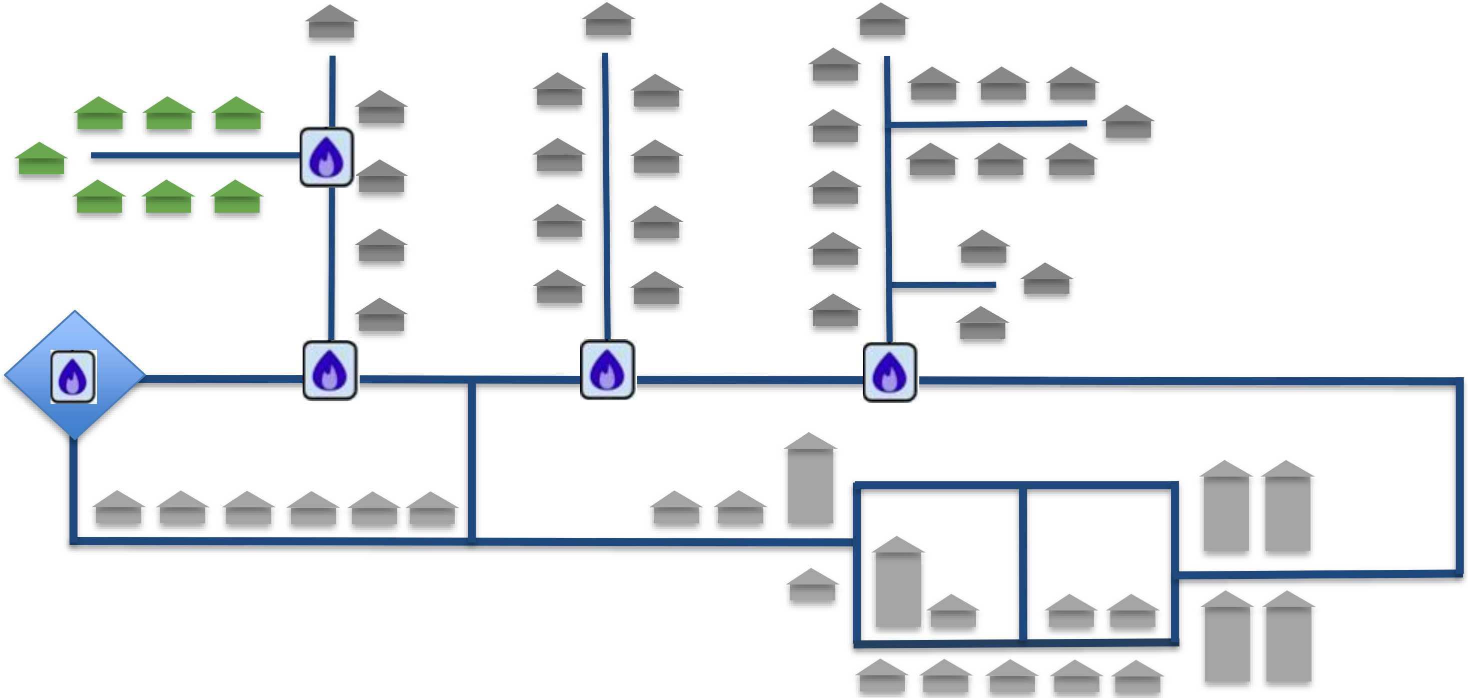


Service to Customer

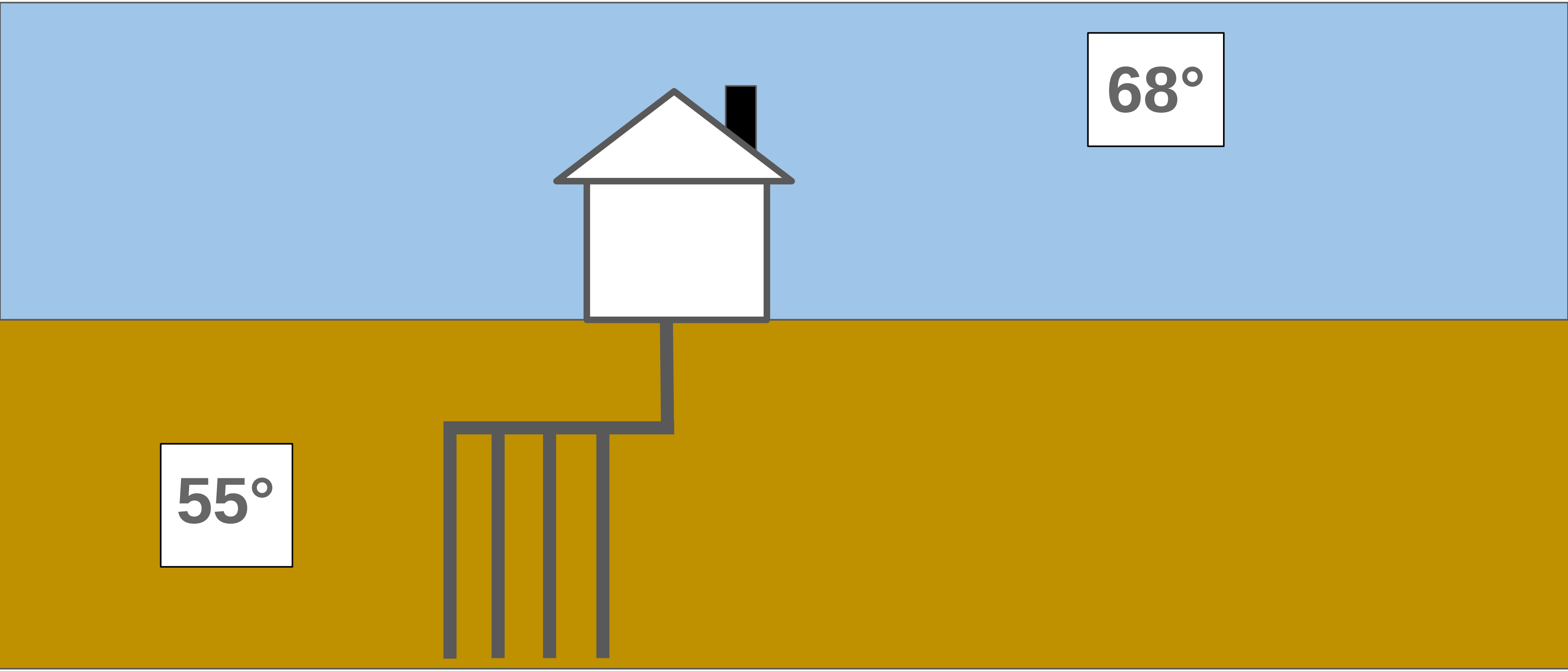
Thermal Loop

Vertical Borehole Array

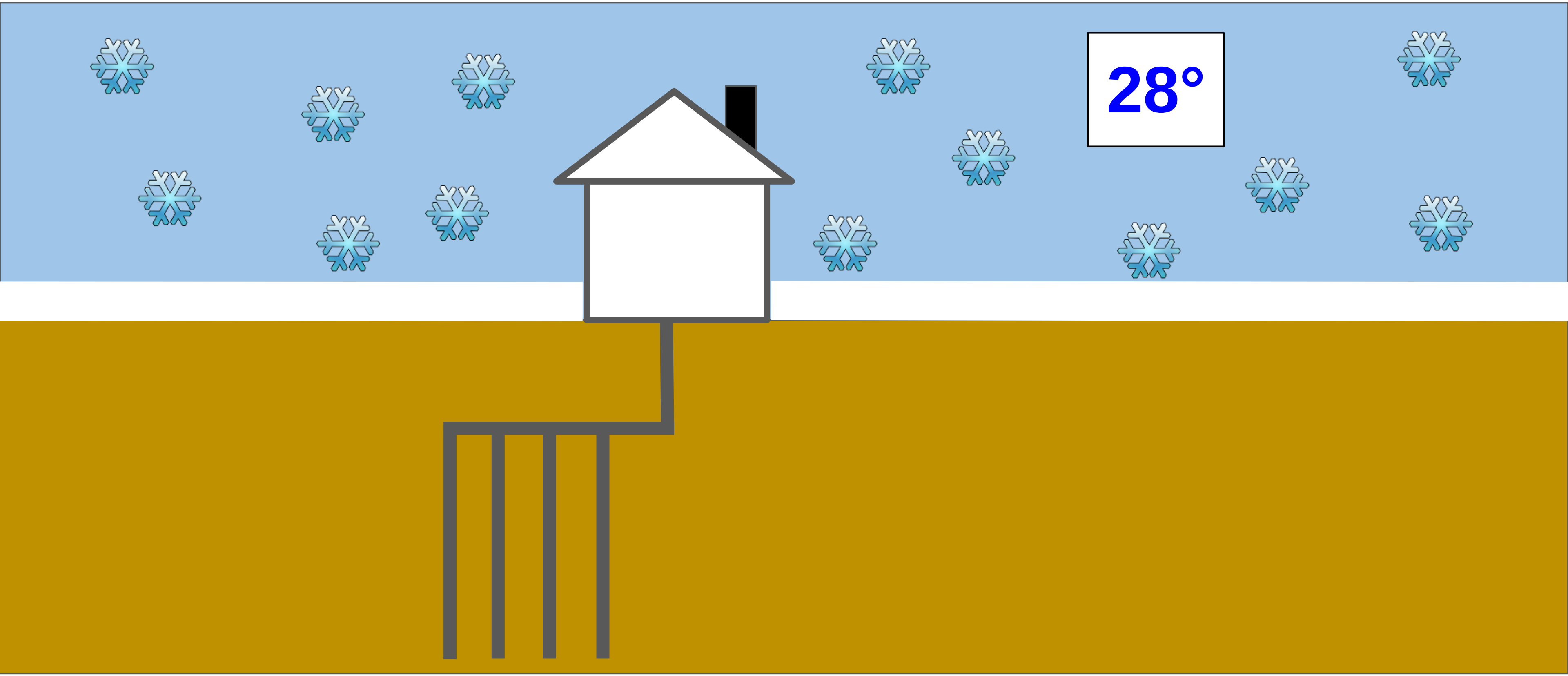
The HEET Grid



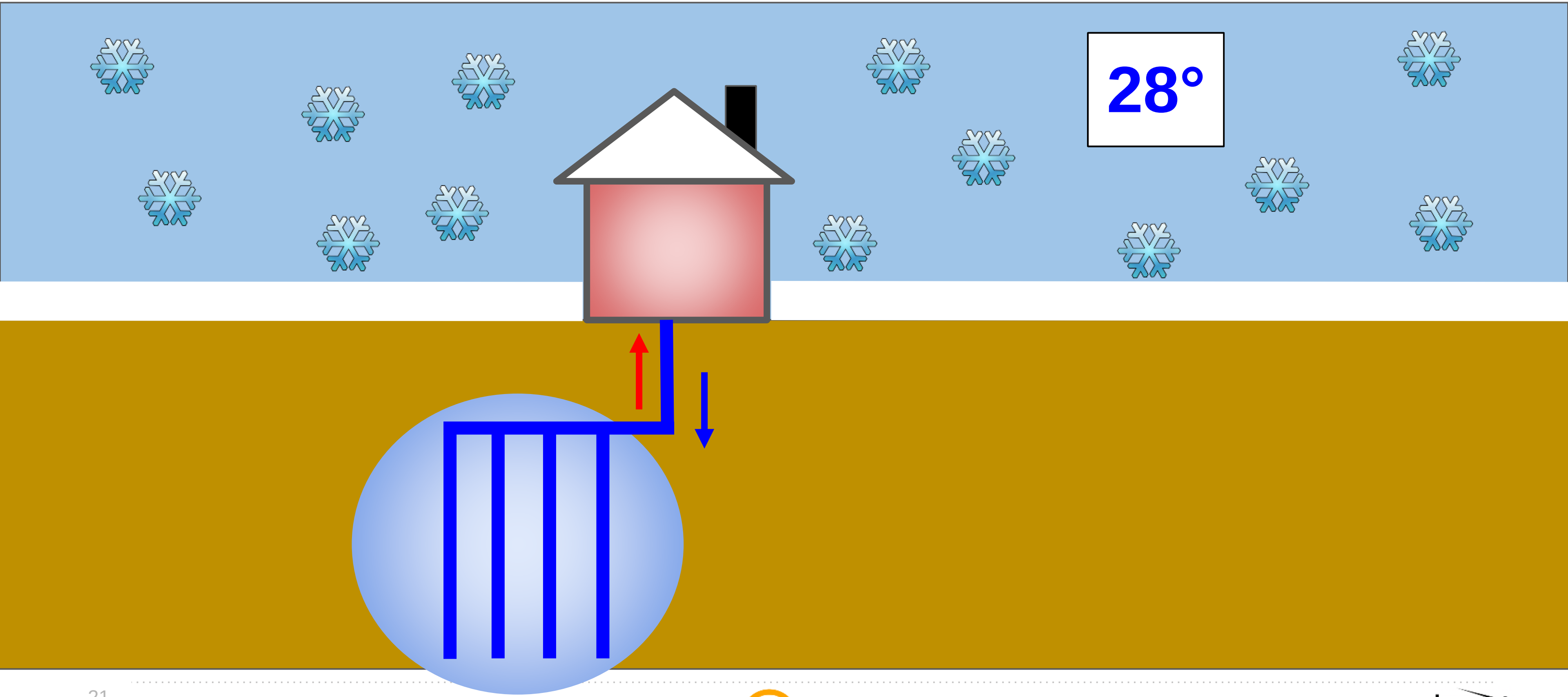
Ground Source Heat Pump



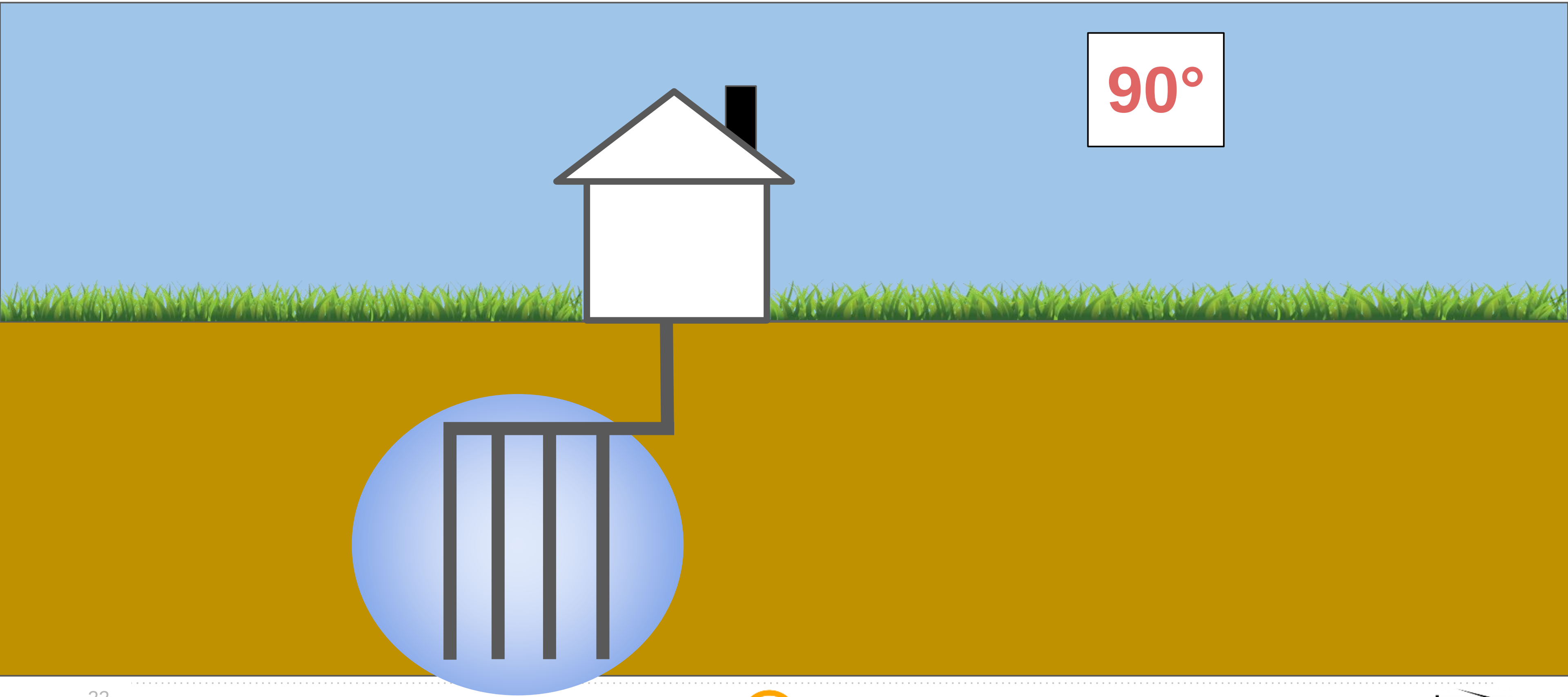
Winter



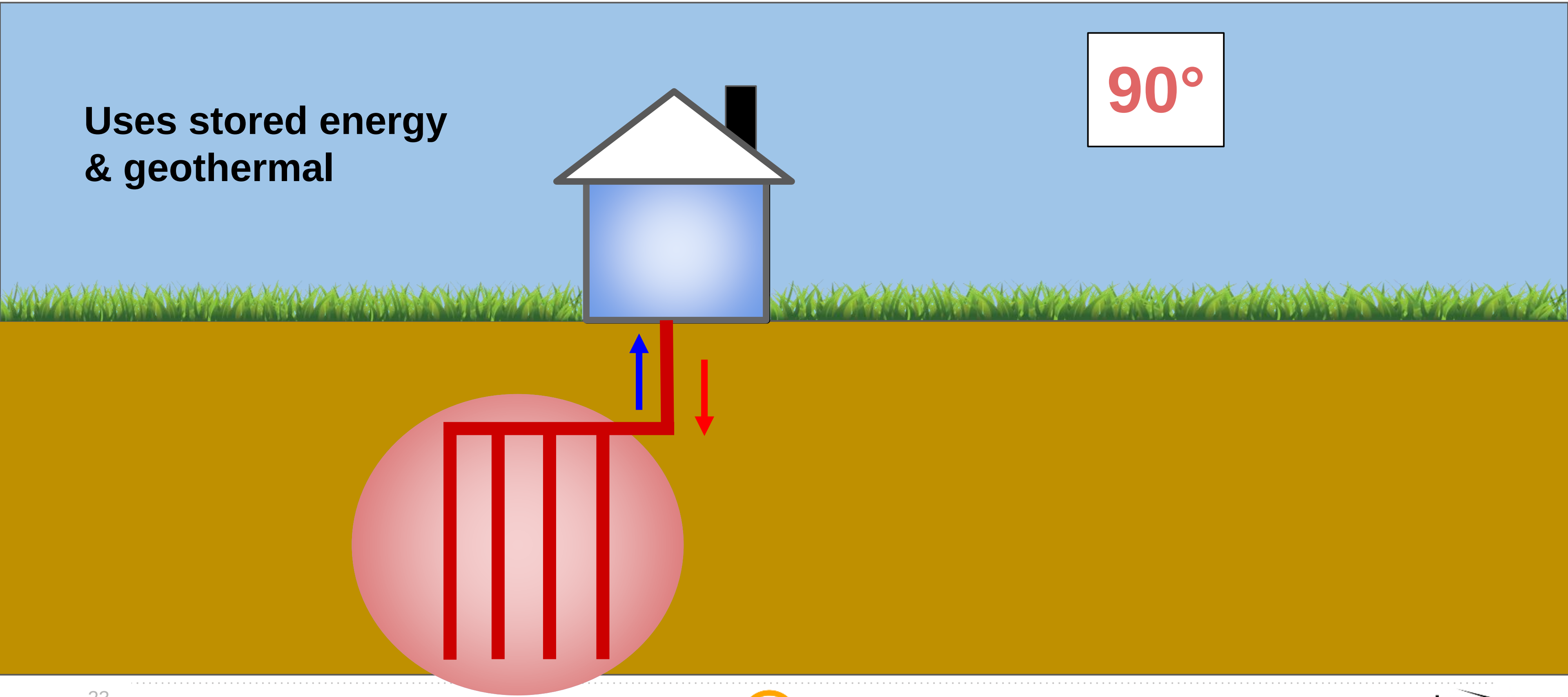
Winter: Heat turned on



Summer

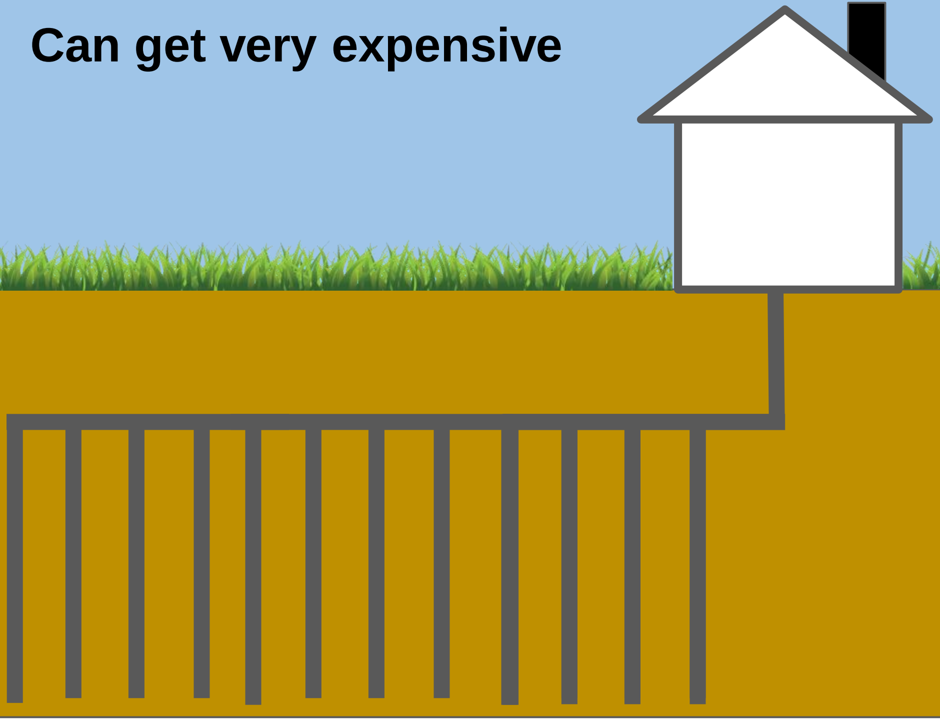


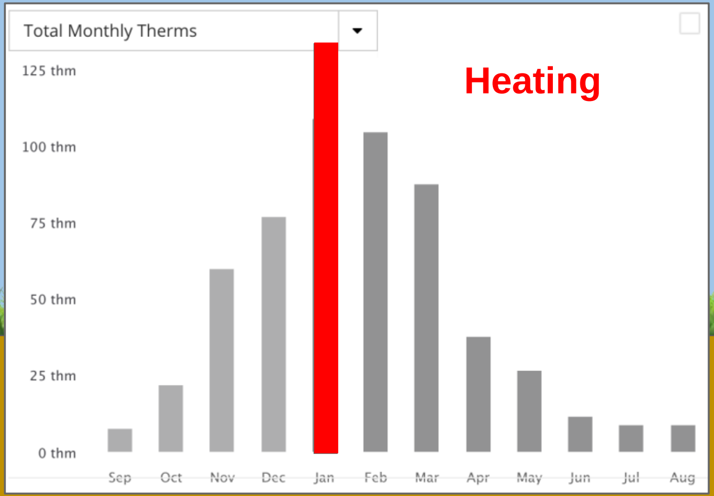
Summer: AC turned on



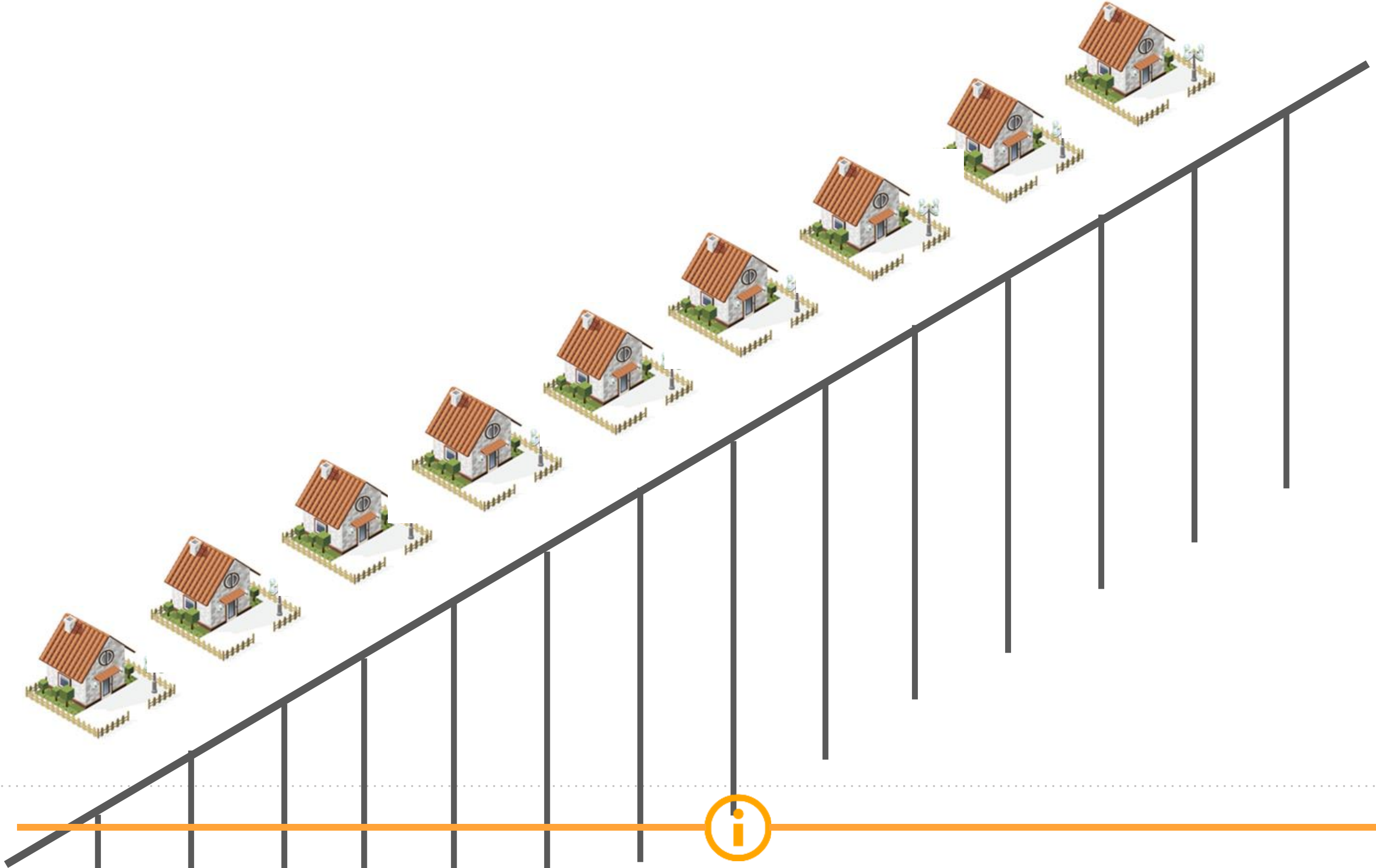
Systems sized for worst heating load/year

Can get very expensive

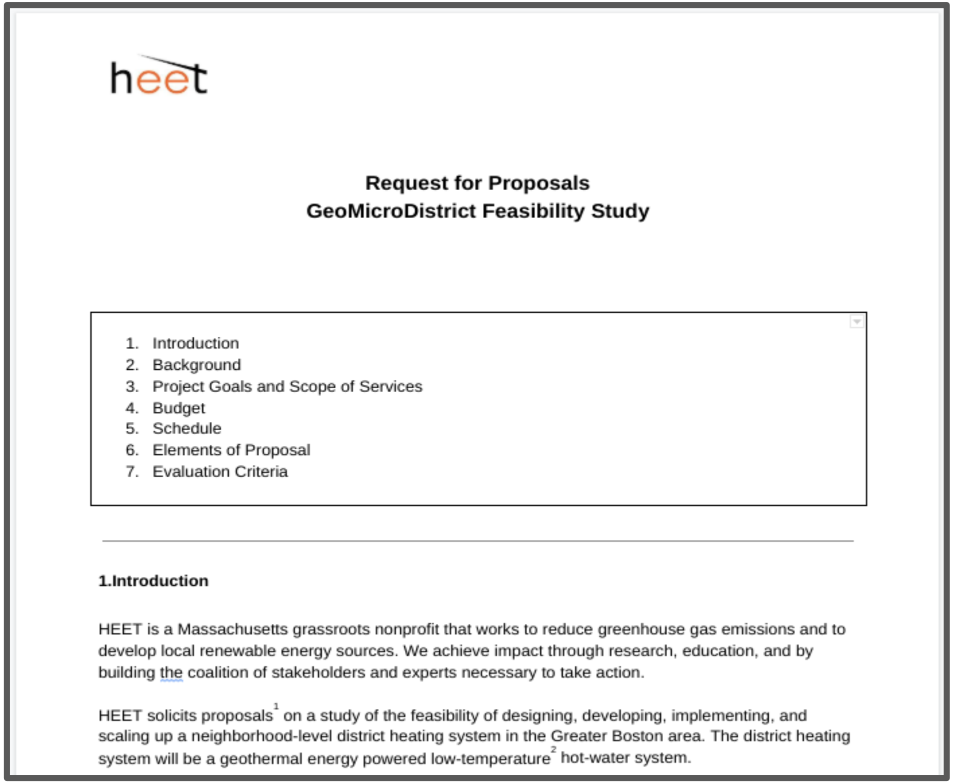




Economies of Scale?



Request for Proposals



Request for Proposals
GeoMicroDistrict Feasibility Study

1. Introduction
2. Background
3. Project Goals and Scope of Services
4. Budget
5. Schedule
6. Elements of Proposal
7. Evaluation Criteria

1.Introduction

HEET is a Massachusetts grassroots nonprofit that works to reduce greenhouse gas emissions and to develop local renewable energy sources. We achieve impact through research, education, and by building the coalition of stakeholders and experts necessary to take action.

HEET solicits proposals[1] on a study of the feasibility of designing, developing, implementing, and scaling up a neighborhood-level district heating system in the Greater Boston area. The district heating system will be a geothermal energy powered low-temperature[2] hot-water system.

Rapid Growth → Innovative Planning

2006

- 3,500 Students
- ~6 City Blocks
- 6 major new complexes or renovations planned in 5 years
- Installed first stand-alone geo system

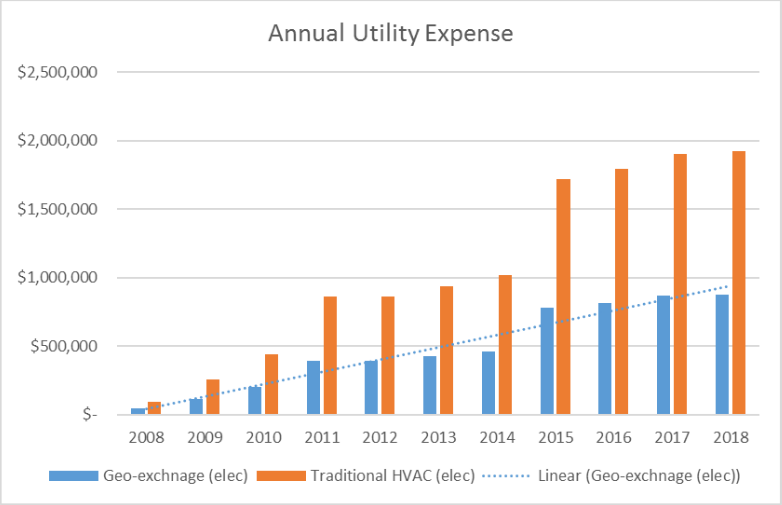
- **2019**

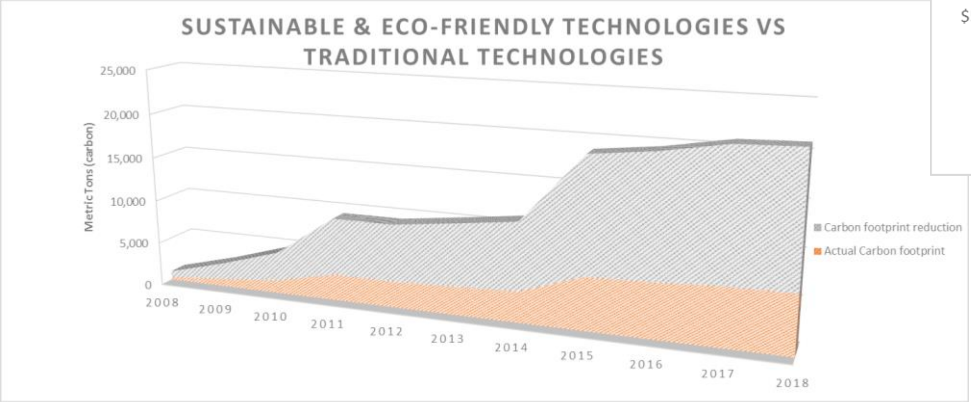
- 11,500 Students
- ~12 City Blocks
- District energy system connects 16 buildings, 5 loopfields
- Expansion continues

Energy & Financial Savings

System cost (post rebates): $8 Million
Annual Energy savings: $1 Million

Carbon Saved: 7,881 metric tons/yr





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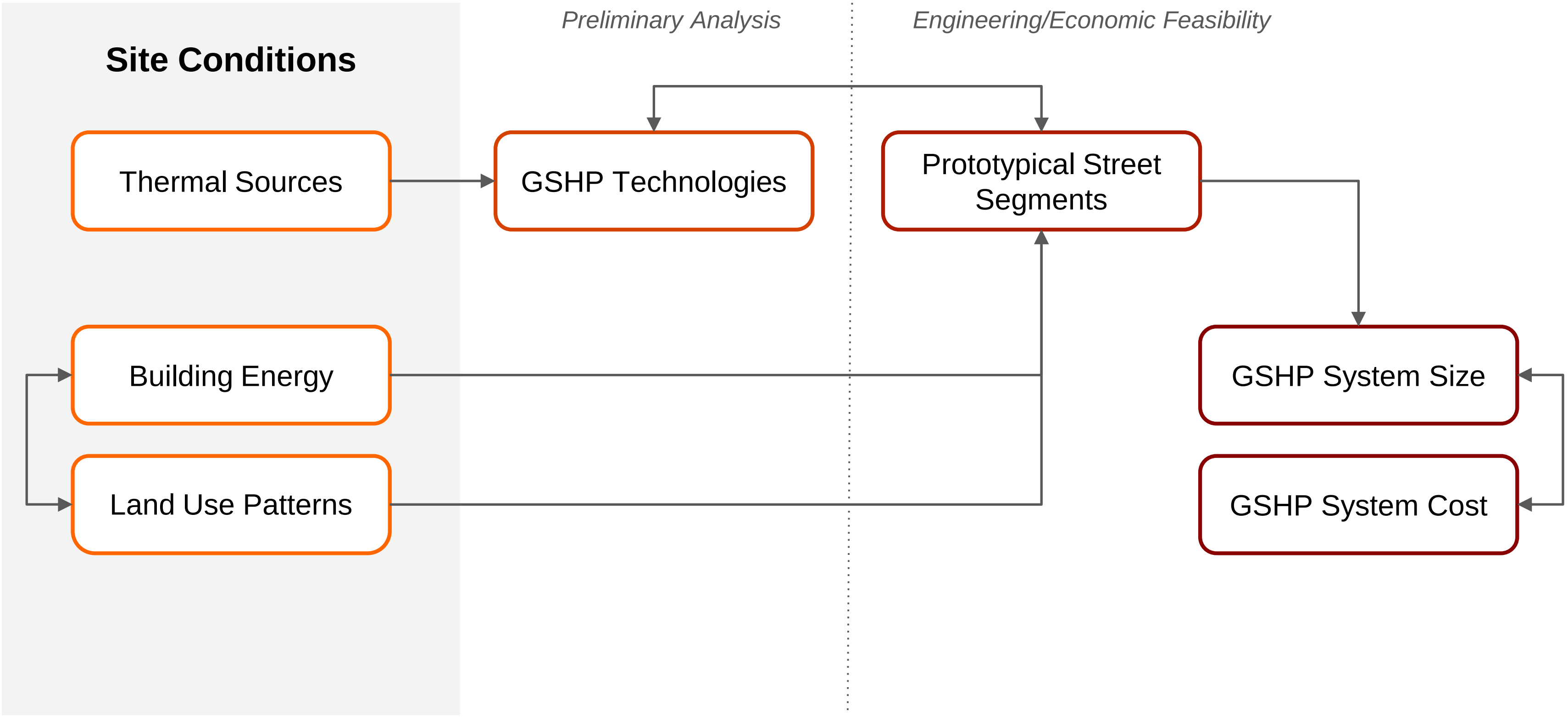
GeoMicroDistrict Feasibility Study

BUROHAPPOLD
ENGINEERING

Project Objective

Explore feasibility of replacing aging gas infrastructure with street-scale geothermal systems.



Preliminary Analysis

Engineering/Economic Feasibility

Site Conditions

Thermal Sources

Building Energy

Land Use Patterns

GSHP Technologies

Prototypical Street Segments

GSHP System Size

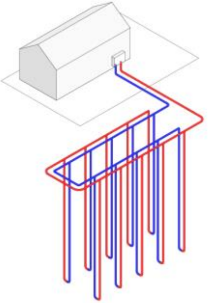
GSHP System Cost

Technologies Considered

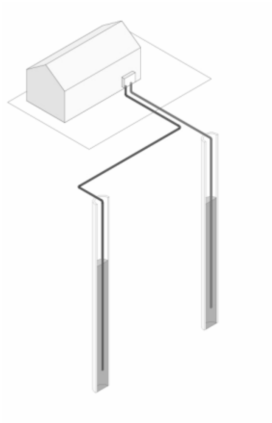
Three ground source heat pump (GSHP) systems evaluated:

1. **Ground-coupled**
2. Groundwater
3. Surface-water

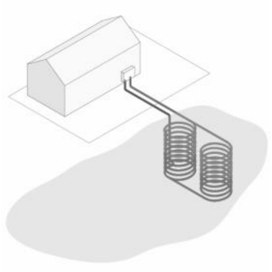
GCHP Closed Vertical



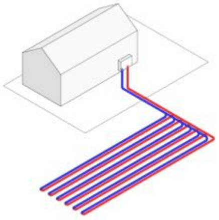
GWHP Open Vertical



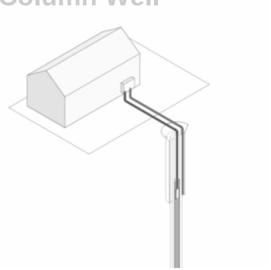
SWHP Closed



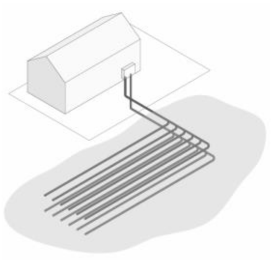
GCHP Closed Horizontal



GWHP Standing Column Well



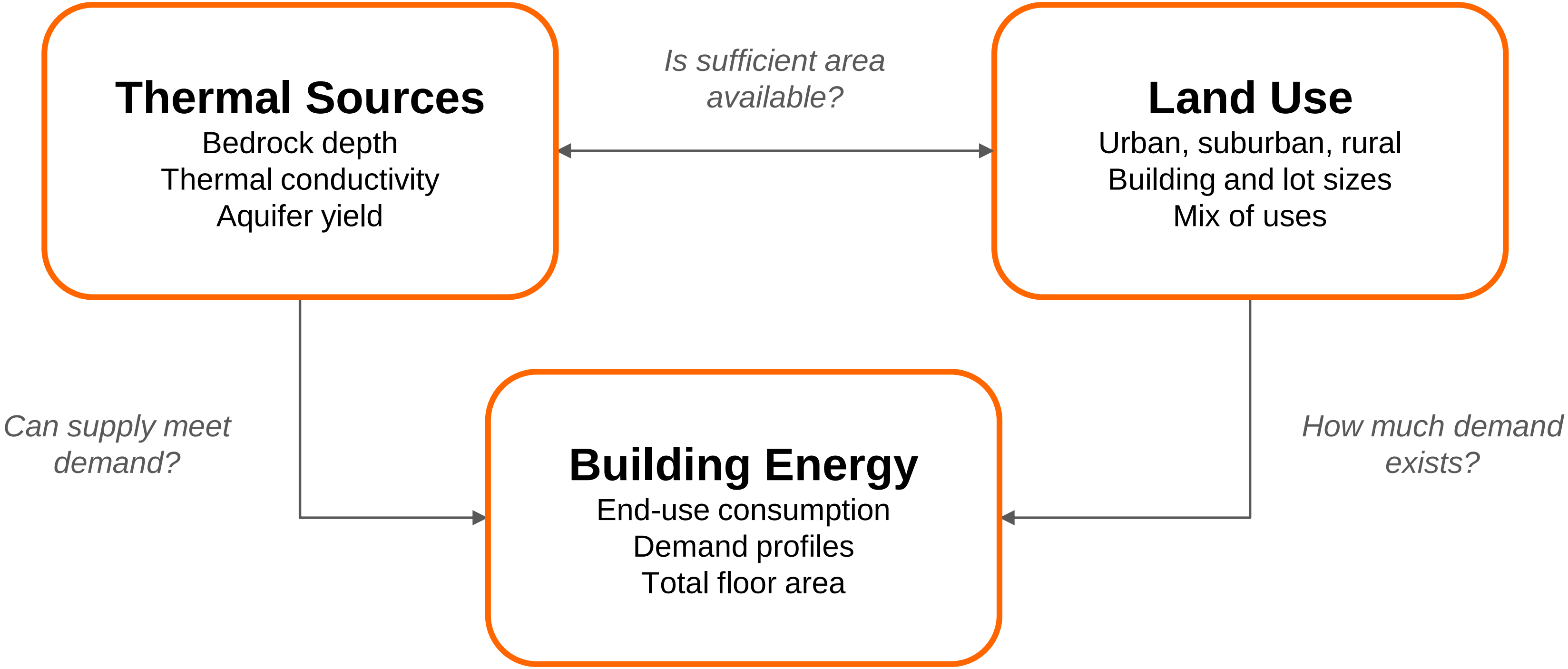
SWHP Open



Preliminary Analysis

Key Considerations

What systems are feasible given the conditions of a certain site?



Thermal Sources

Bedrock depth
Thermal conductivity
Aquifer yield

Is sufficient area available?

Land Use

Urban, suburban, rural
Building and lot sizes
Mix of uses

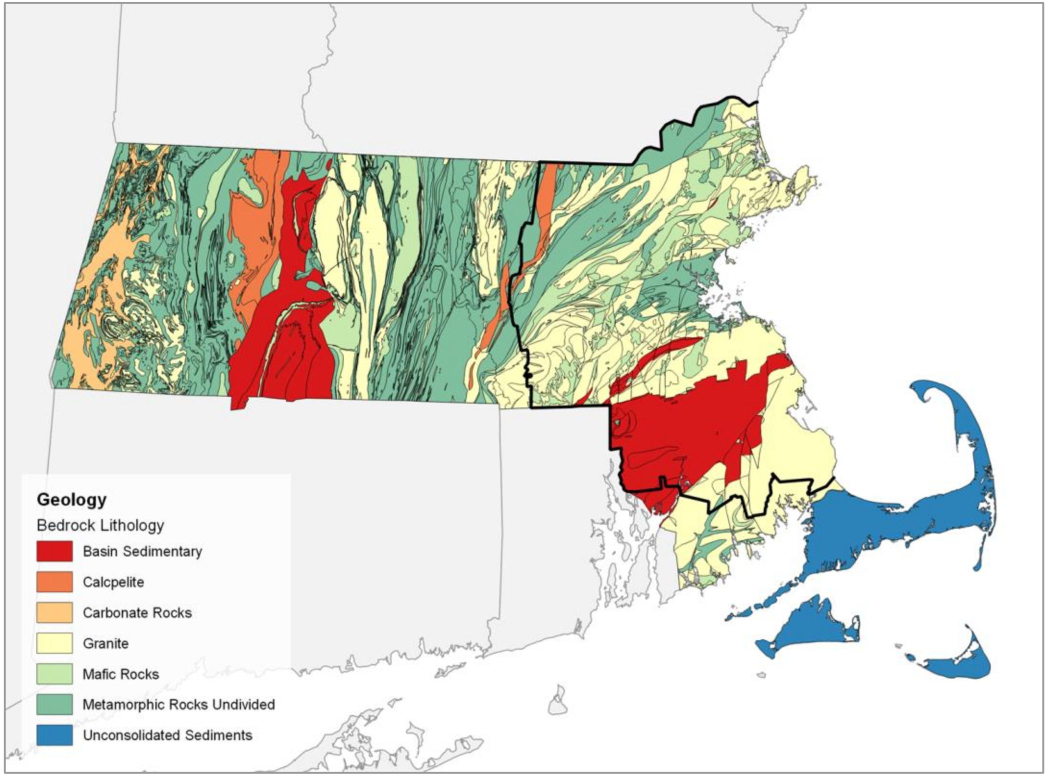
Can supply meet demand?

Building Energy

End-use consumption
Demand profiles
Total floor area

How much demand exists?

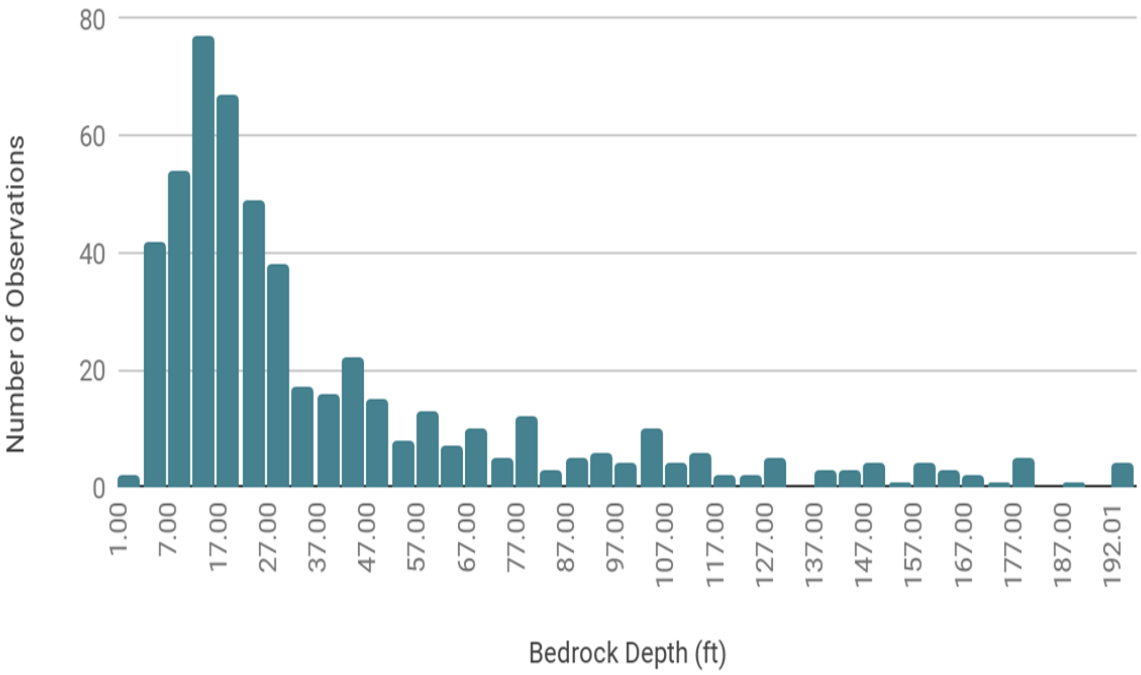
Geology



Granite and metamorphic rock, which provide a greater rate of heat extraction, found frequently through Massachusetts.

Source: BuroHappold analysis; MassGIS/USGS

Bedrock Distribution Depth

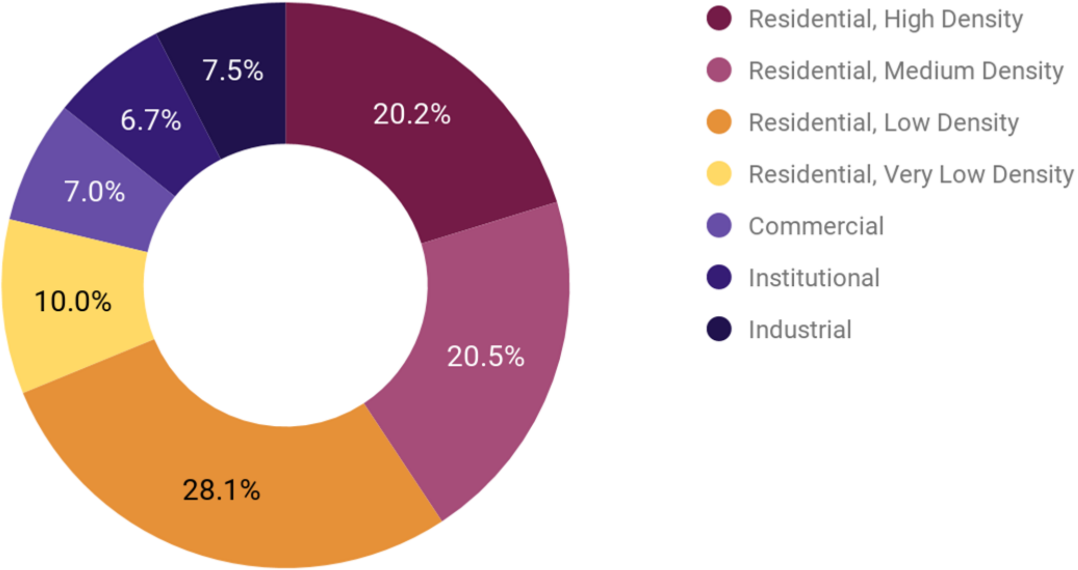


Bedrock depth typically between 5 and 40 feet. Drilling costs are typically lower where bedrock is shallow.

Source: BuroHappold analysis; MA EEA

Land Use in Massachusetts

Total Area by Land Use

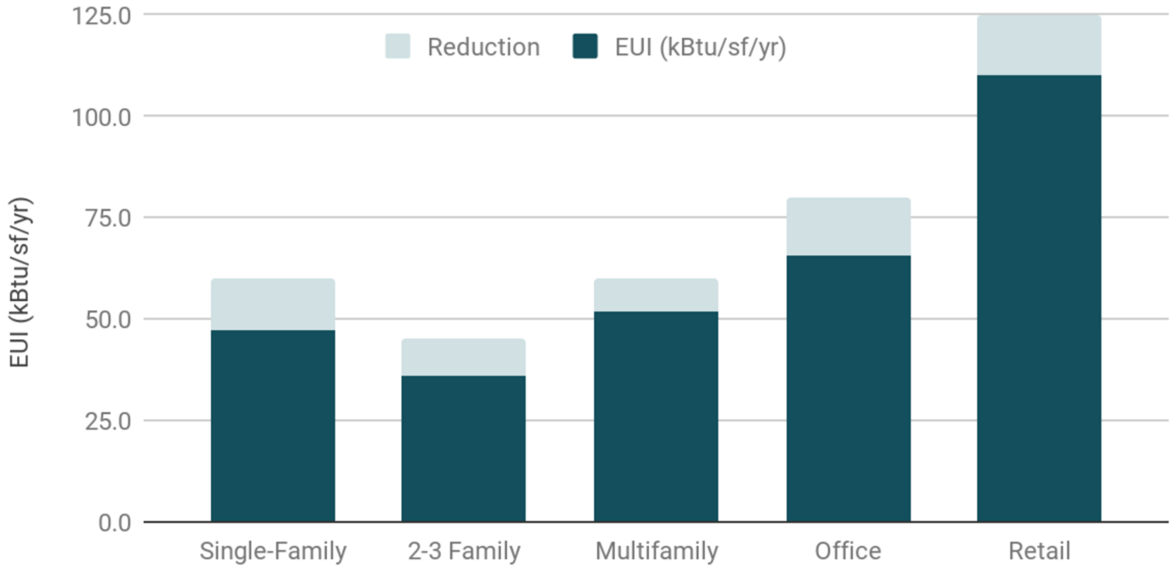


Nearly 80% of developed land in Massachusetts is residential, a majority of which is low and medium density housing.

Source: BuroHappold analysis; MassGIS

Energy Efficiency Annual Energy Consumption

Energy Use Intensity (EUI) by Typology



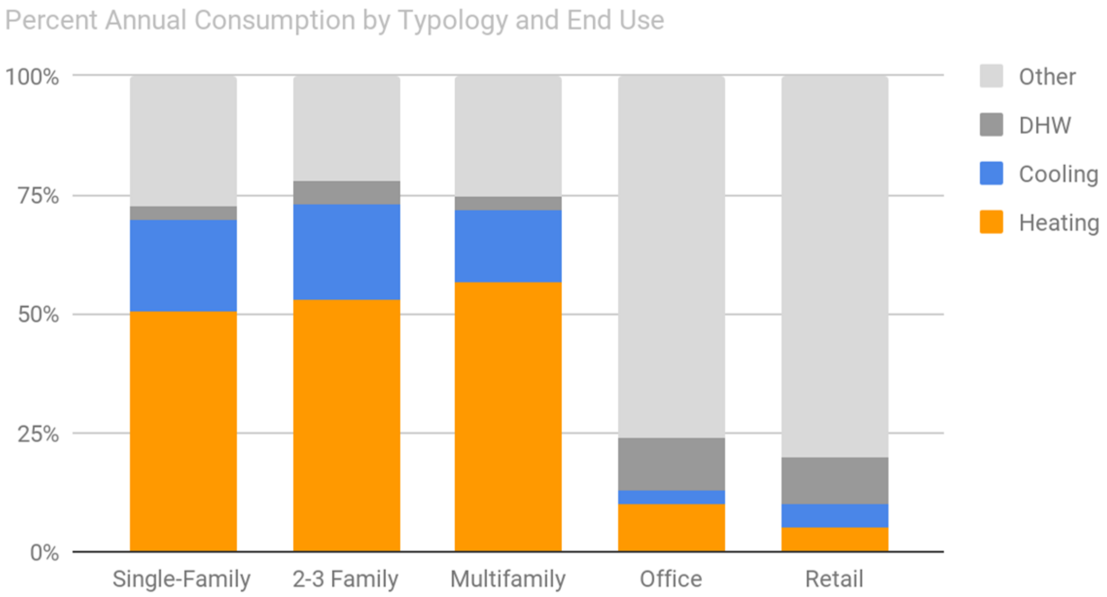
Energy profiles created for representative building types. Additional energy efficiency measures (insulation, air sealing, cool roofs) were applied to baseline consumption.

Source: BuroHappold analysis; MA DOER; U.S. DOE; U.S. EIA; EPRI

BUROHAPPOLD ENGINEERING heet

Energy Efficiency End Use Energy Consumption

Percent Annual Consumption by Typology and End Use



The resulting end use profiles were used to estimate heating and cooling loads for a street-scale GSHP system.

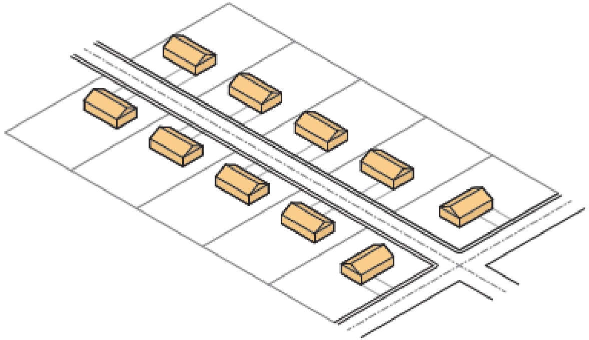
Source: BuroHappold analysis; MA DOER; U.S. DOE; U.S. EIA; EPRI

Feasibility Study

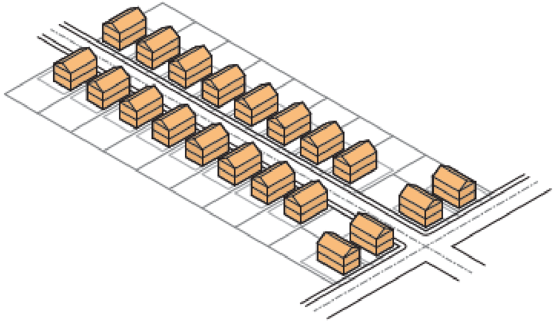
Modeling Approach

Prototype Street Segments

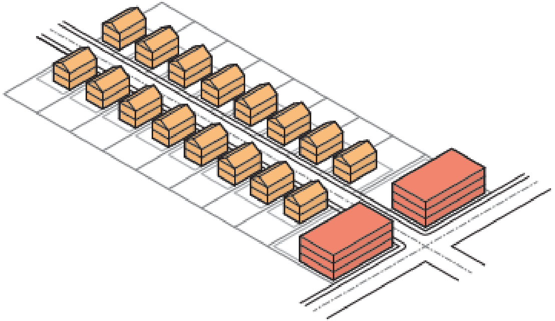
Four prototype street segments (PSS) created and analyzed:



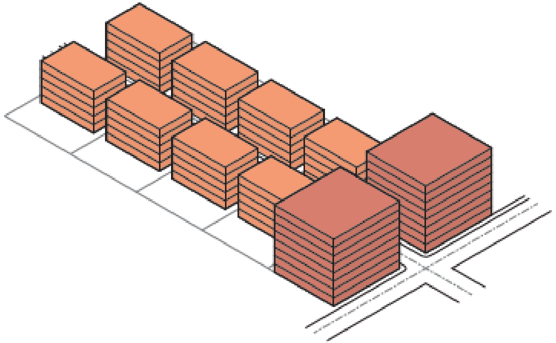
Low density residential



Medium density residential



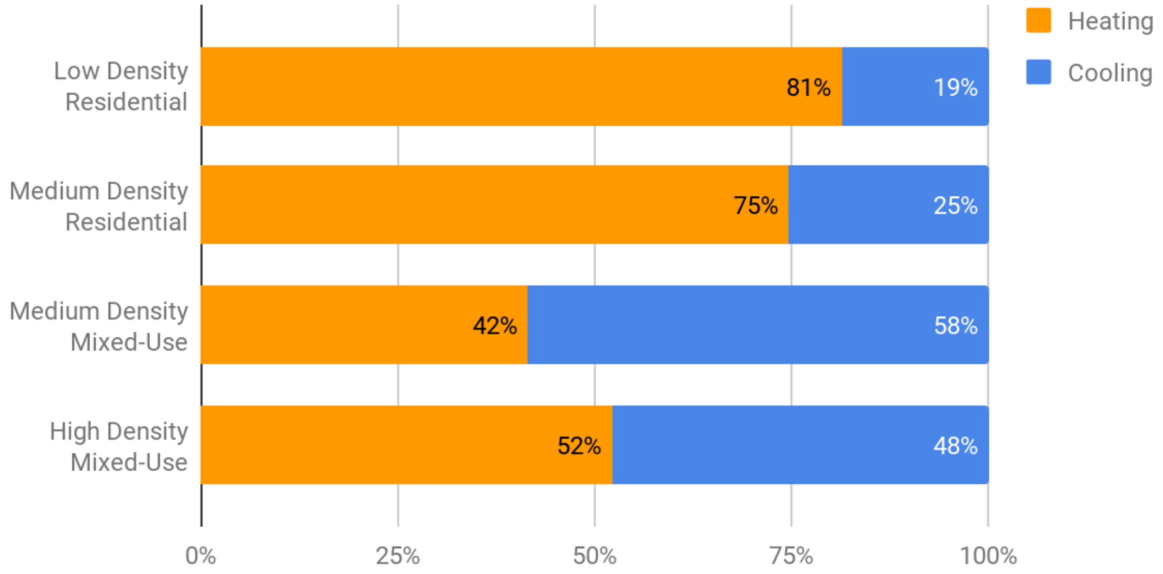
Medium density mixed-use



High density mixed-use

Prototype Street Segments Heating and Cooling Loads

Annual Heating and Cooling Consumption



Heating and cooling loads for each PSS were based on building energy profiles, and account for overlaps in demand.

Key Assumptions

- **Only GCHP closed horizontal and vertical systems modeled.**
- **Heat pumps in individual buildings connected to shared loop in street.**
- Energy efficiency measure applied prior to GCHP connection.
- DHW provided by electric heat pumps installed as part of conversion.
- Dry gravel/sand soil with metamorphic bedrock 35 feet deep.
- 40-foot wide right of way (ROW), with 2-foot wide utility ROW.
- Maximum borehole depth of 500 feet.
- **10 % seasonal energy balance maintained.**

GSHP installations in private yards and other open spaces were not modeled, but are viable options for increasing system capacity, where available.

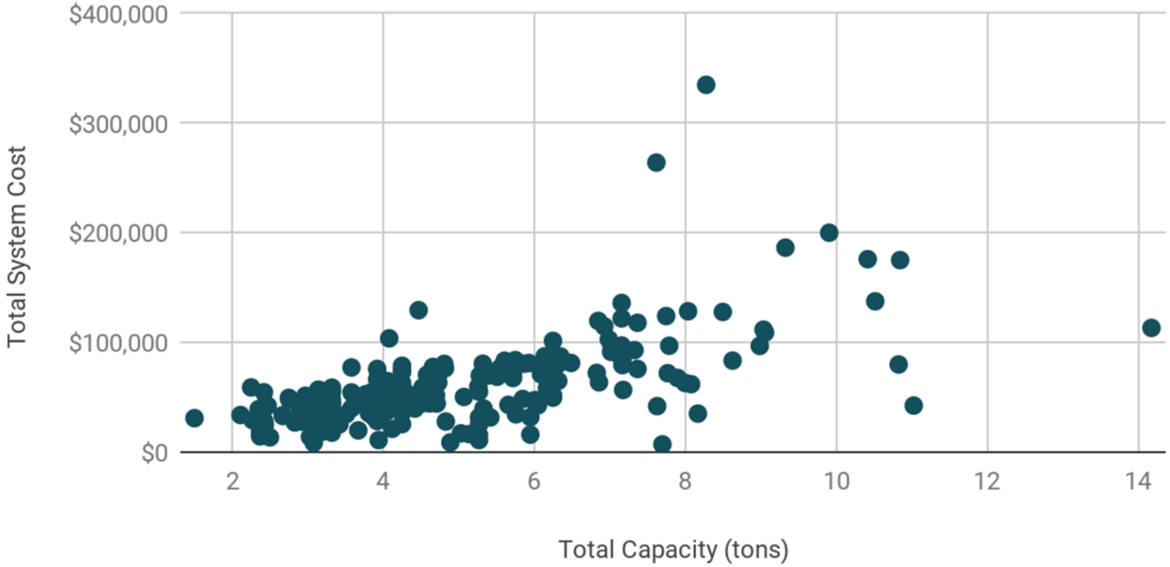
Seasonal Energy Balance

- **Imbalance between heating and cooling loads can alter the ground temperature and cause a long-term decline in system performance.**
- Issue can be corrected by undersizing the system, or oversizing the system and connecting with an external means of adding/rejecting heat.
- External sources include other solar hot water systems, waste heat from neighboring buildings, and waste heat from industrial processes.

Interconnecting multiple street-scale GSHP systems could increase load diversity and help maintain seasonal energy balance.

Existing GSHP System Installation Costs

Total System Cost Versus Total Capacity



Wide range of reported installation costs, regardless of system type and size.

Source: BuroHappold analysis; MassCEC

Customer Costs:

GCHP Vertical System Installation Costs:

- Energy Efficiency Retrofit:
  - Air sealing and Insulation &White/cool roof
- GCHP Conversion:
  - Heat pump installation, Backup ASHP Installation, Gas to electric conversion
- New appliances
  - Electric domestic hot water heater, Electric stove/oven & Electric dryer

Incentives and Programs considered:

- Residential Customers:
  - Mass Save Weatherization Program, Mass Save DHW Heat Pump rebate, Mass Save Heat Loan
- Commercial Customers:
  - Commercial-scale GSHP rebate, Mass Save DHW Heat Pump rebate

Utility Costs:

Installation Costs Considered:

- Equipment and labor
  - Drill rig setup/breakdown, Borehole drilling, Loop piping and installation, Circulating fluid, System pumps
- Other allowances:
  - Design and engineering, Permits and approvals, Overhead, profit, and contingency, Economies of scale

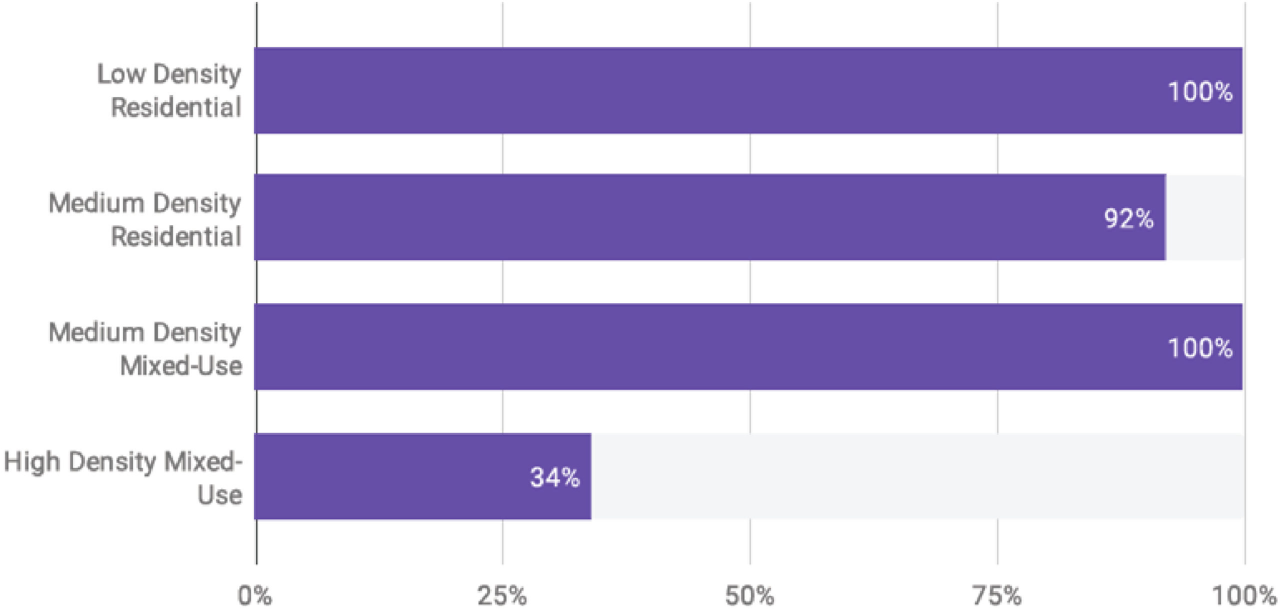
Rates Depend on:

- Required revenue
  - ? year amortization period.
  - ? return on equity applied to GCHP installation, maintenance, and repair/replacement costs.
  - Operational costs passed directly to customers.

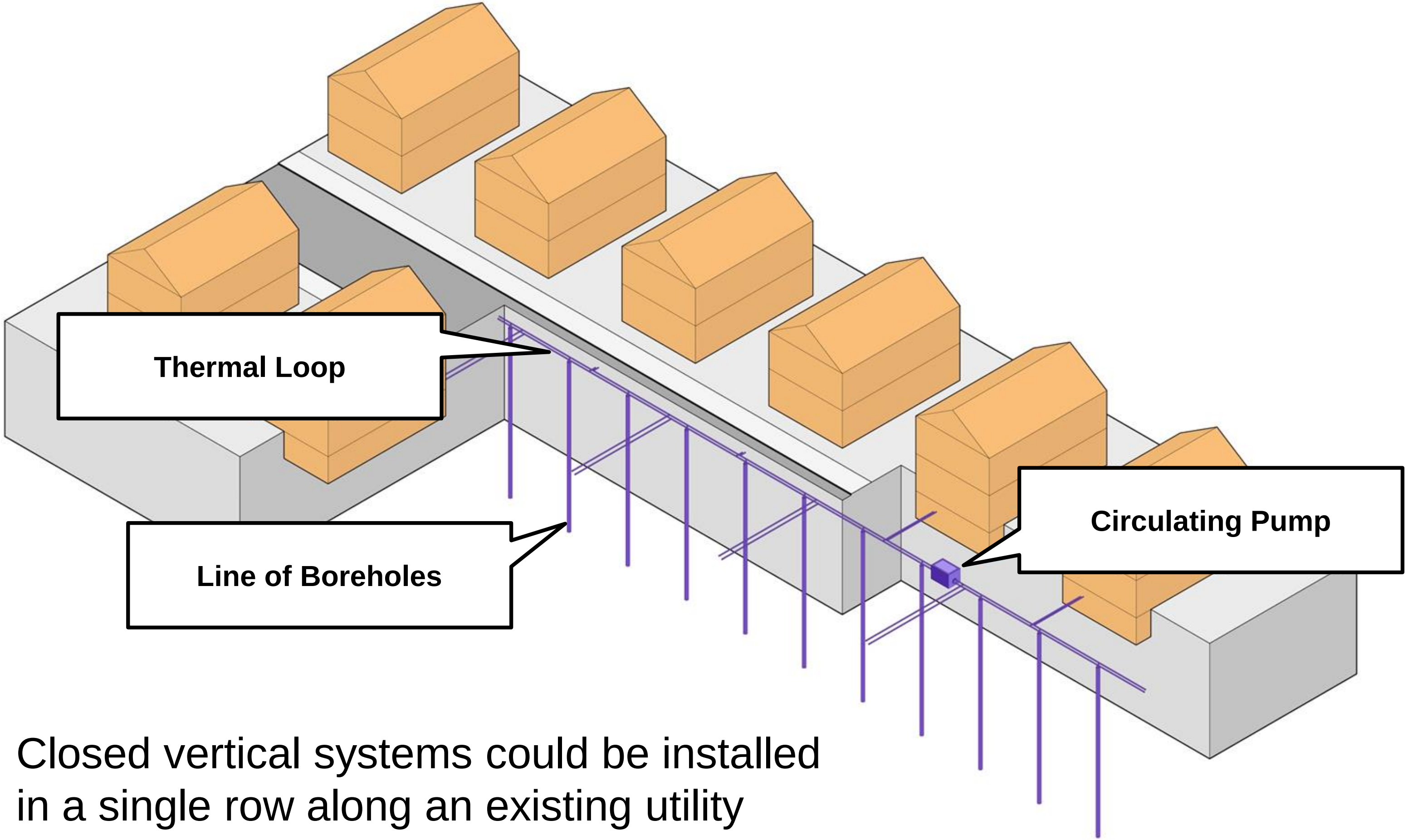
Feasibility Study
Results

Technical Feasibility: GCHP Closed Vertical

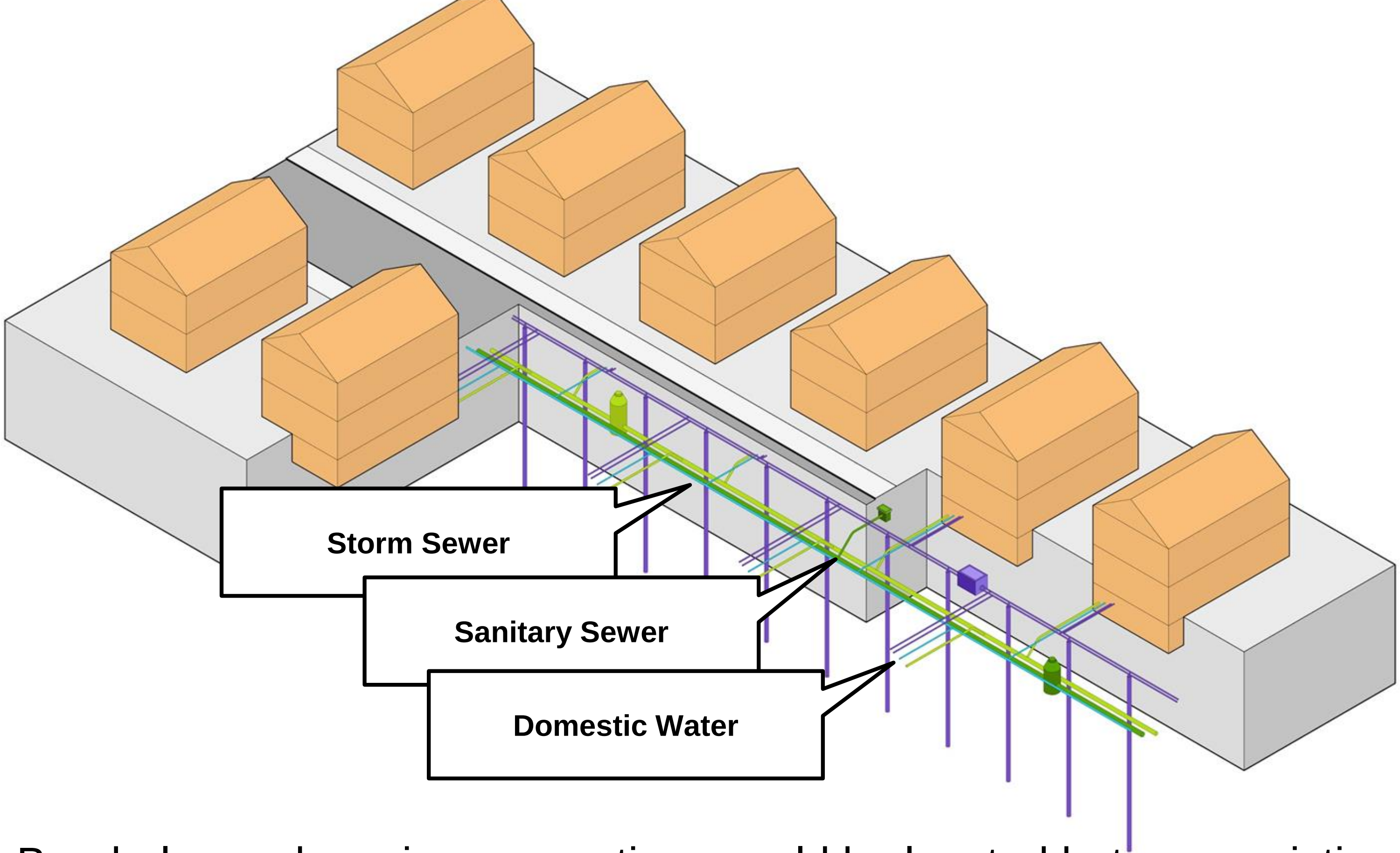
Annual Thermal Energy Loads Met (Interconnected)



Closed vertical systems were able to meet 100% of heating and cooling loads for 2 of the 4 Prototype Street Segments modeled.



Closed vertical systems could be installed in a single row along an existing utility corridor.


Storm Sewer

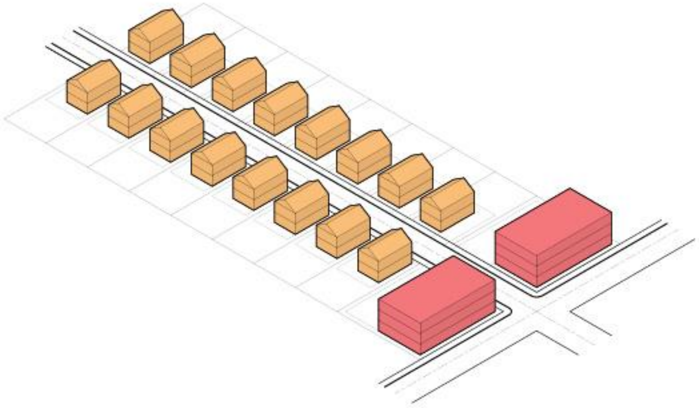
Sanitary Sewer

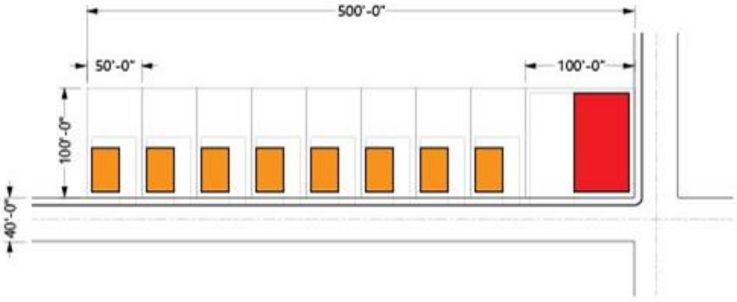
Domestic Water

Boreholes and service connections could be located between existing infrastructure.

Medium Density Mixed-Use

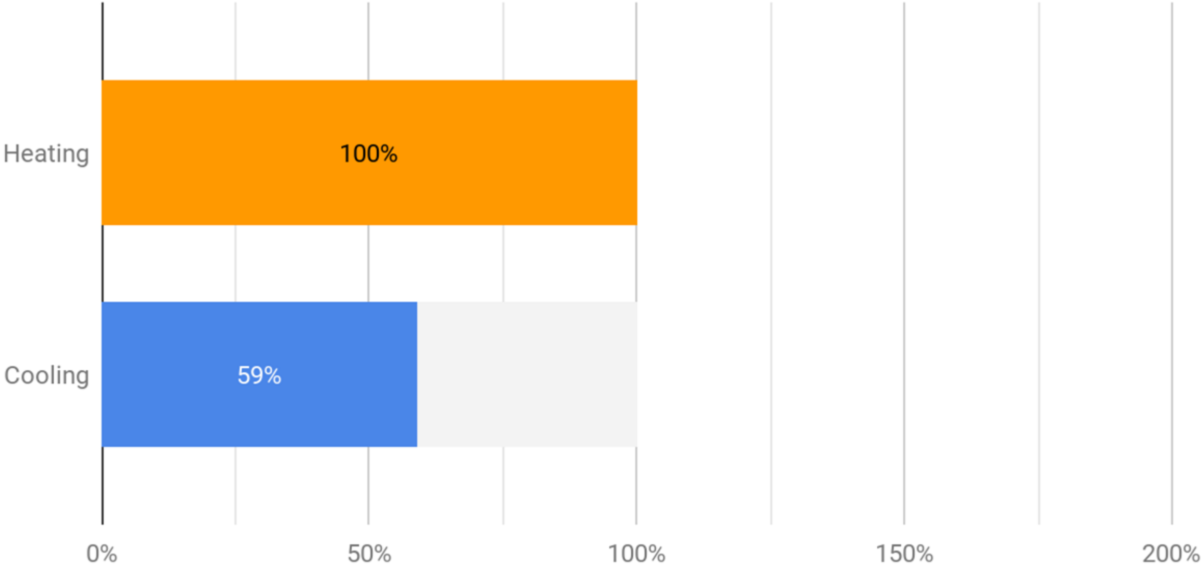
- **16 2-3 family homes**
- **2 commercial buildings**
- 75,000 gsf total area
- 5,535 MBtu/yr consumption
- 101 tons heating demand
- 39 tons cooling demand
- 600 ft. long ROW
- 2 lines of 30 boreholes





GCHP Closed Vertical: Balanced

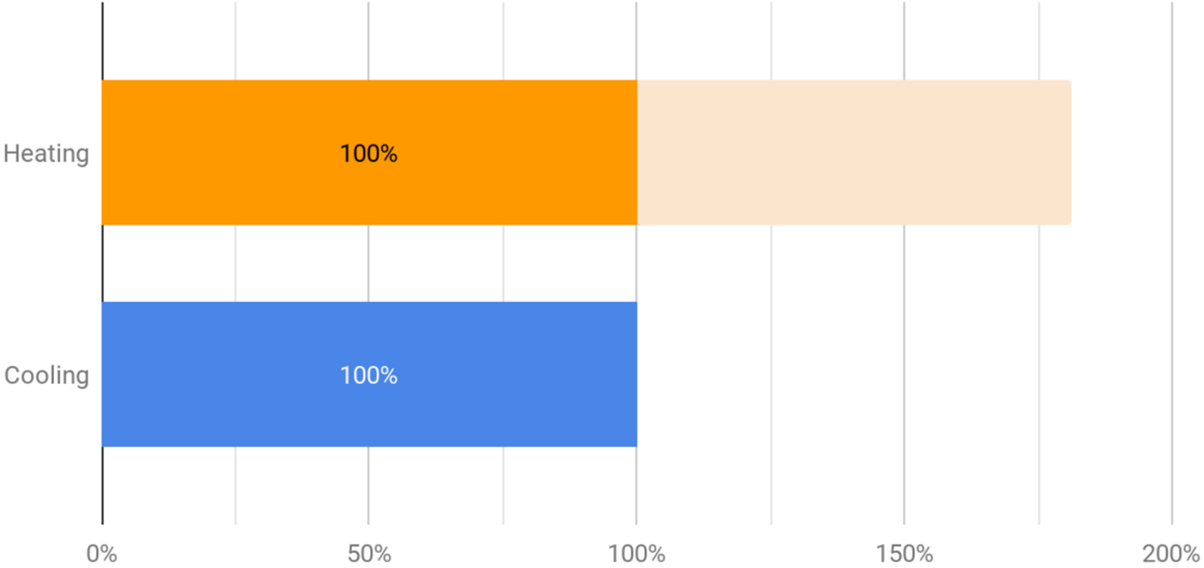
Medium Density Mixed-Use



To meet our criteria for seasonal energy balance, cooling loads were curtailed to prevent overheating of the ground.

GCHP Closed Vertical: Interconnected

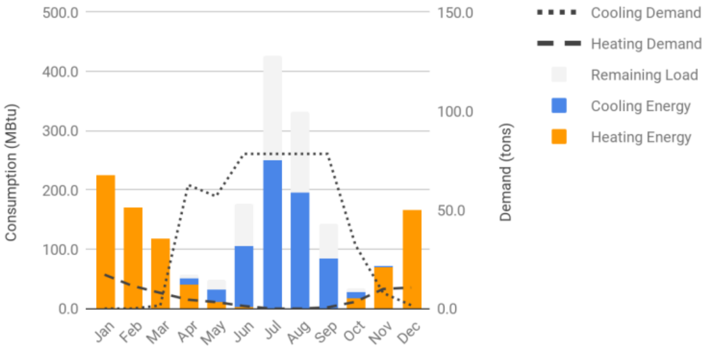
Medium Density Mixed-Use



However, if excess heating capacity could be exported through an interconnected system, 100% of loads could be met.

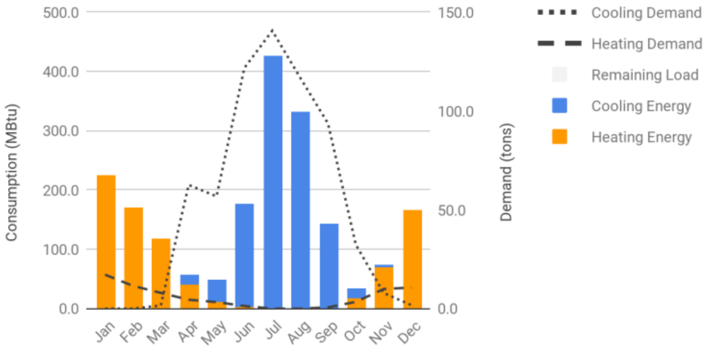
GCHP Closed Vertical: Balanced

Medium Density Mixed-Use



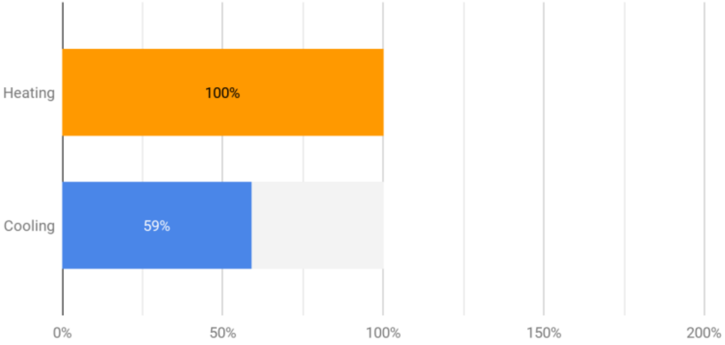
GCHP Closed Vertical: Interconnected

Medium Density Mixed-Use



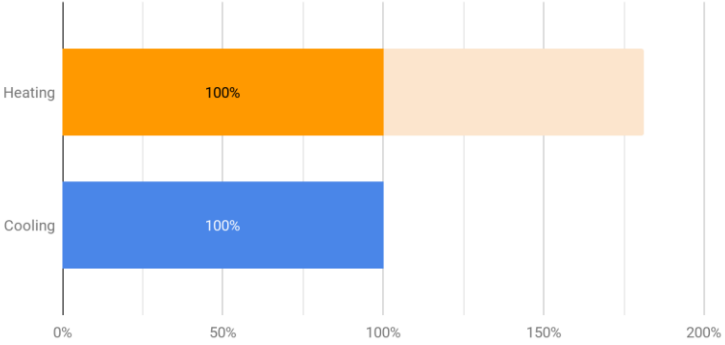
GCHP Closed Vertical: Balanced

Medium Density Mixed-Use



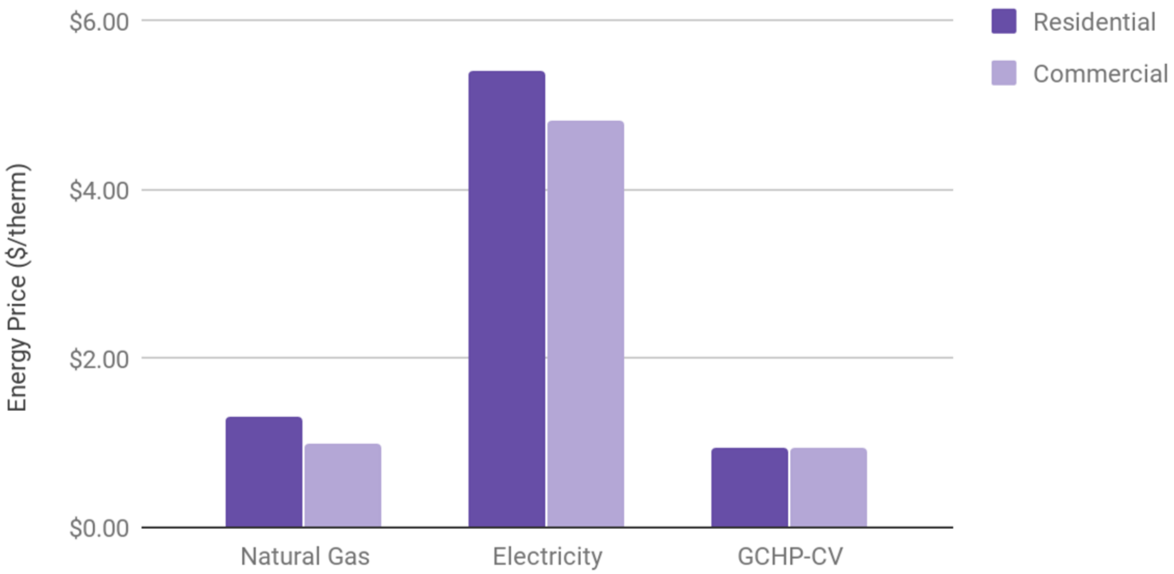
GCHP Closed Vertical: Interconnected

Medium Density Mixed-Use



Comparison of Energy Prices

Medium Density Mixed-Use, GCHP Closed Vertical

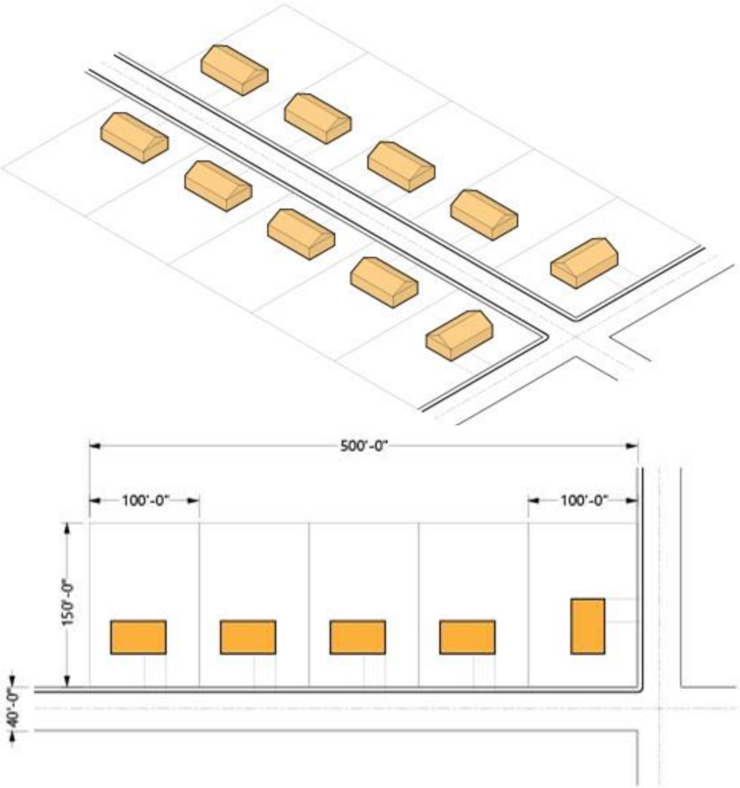


For a balanced system, the estimated price of utility-provided GCHP heating/cooling is lower than both gas and electricity.

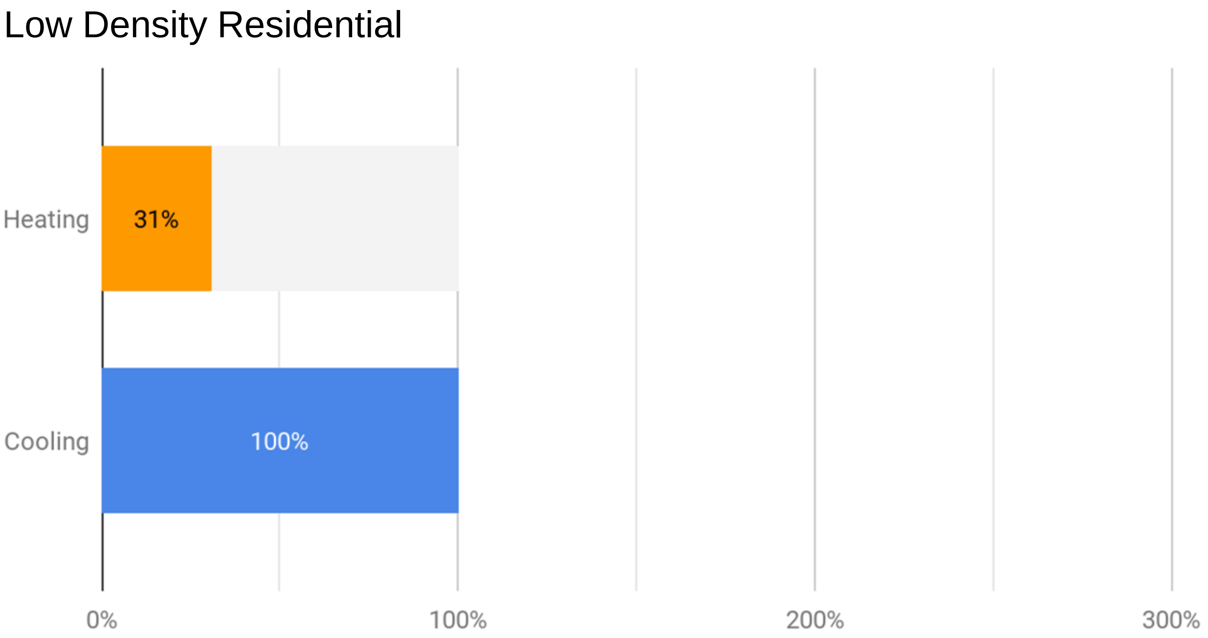
Source: BuroHappold analysis; U.S. EIA

Low Density Residential

- **10 single-family homes**
- 30,000 gsf total area
- 703 MBtu/yr consumption
- 40 tons heating demand
- 30 tons cooling demand
- 650 ft. long ROW
- 2 lines of 32 boreholes



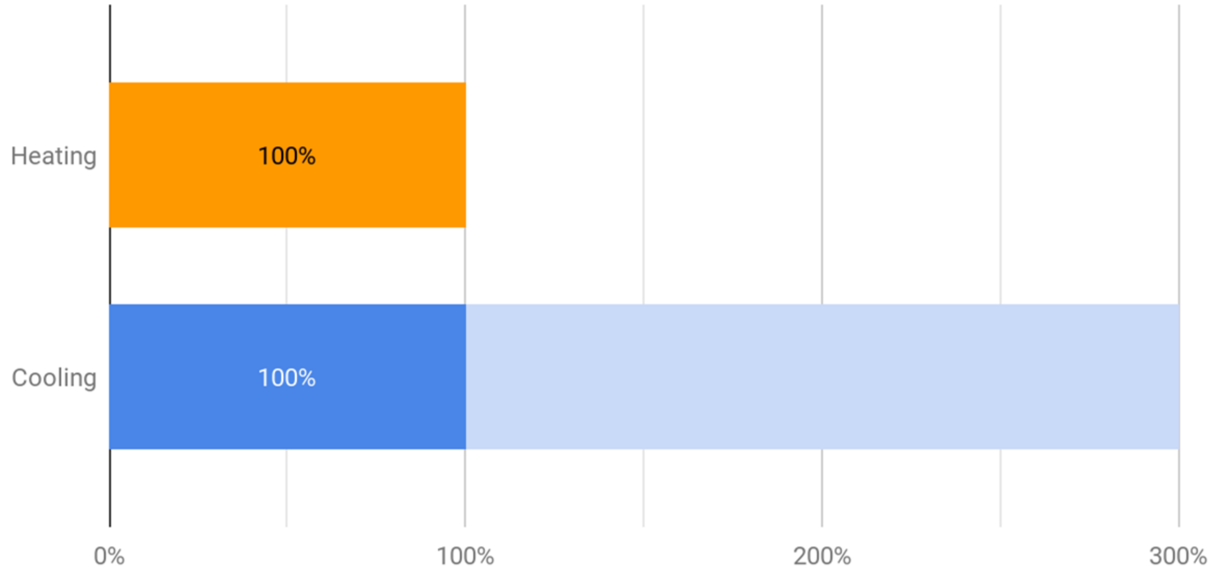
GCHP Closed Vertical: Balanced



To meet our criteria for seasonal energy balance, heating loads were curtailed to avoid overcooling of the ground.

GCHP Closed Vertical: Interconnected

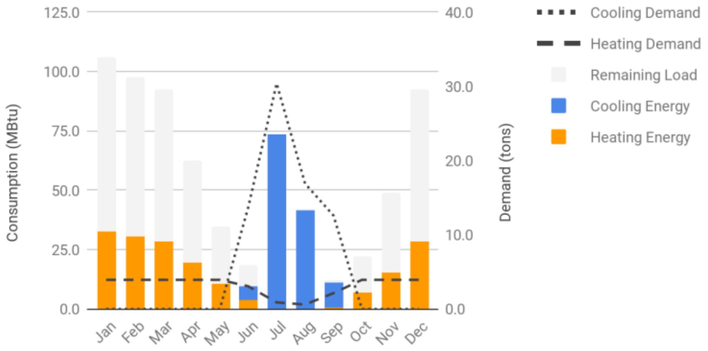
Low Density Residential



However, if excess cooling capacity could be exported through an interconnected system, 100% of loads could be met.

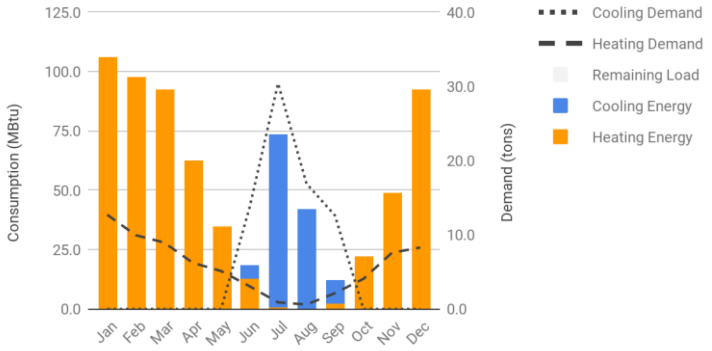
GCHP Closed Vertical: Balanced

Low Density Residential



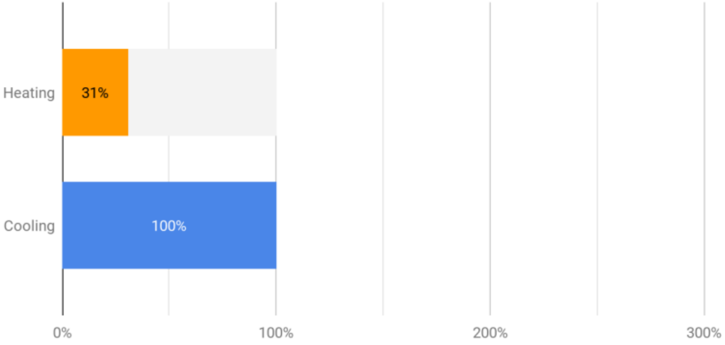
GCHP Closed Vertical: Interconnected

Low Density Residential



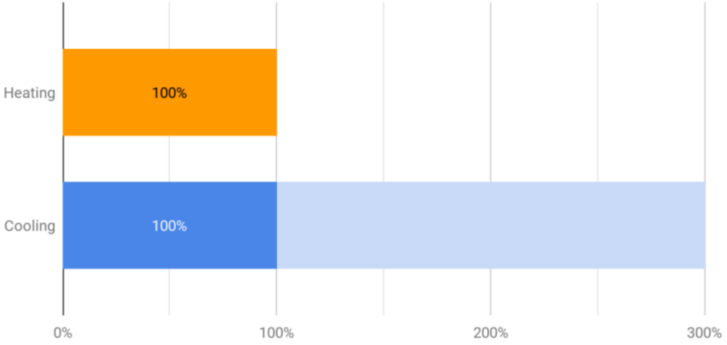
GCHP Closed Vertical: Balanced

Low Density Residential



GCHP Closed Vertical: Interconnected

Low Density Residential



Technical Observations

- **Seasonal imbalance, not site area, is the primary limitation.**
  - Diverse heating and cooling loads critical to long-term performance.
  - Extent of thermal degradation is site specific and should be studied on a case-by-case basis.
  - Imbalanced conditions can be resolved with external thermal sources, or the addition or interconnection of other, more diverse loads.
- **Closed Vertical systems are feasible for all conditions studied.**
  - Greater installation area or borehole depth may be needed achieve full capacity.
  - Interconnection needed in most cases to address seasonal imbalance.
- **Closed Horizontal systems may be feasible for certain site conditions.**
  - Greater installation area may be needed to achieve full capacity.
  - Performance increases where ground has high thermal conductivity (e.g., moist soils).

Economic Observations

- **Installation and conversion costs vary widely. More data is needed.**
  - Estimated payback for utilities and customers varies from 4 to 60 years.
  - Empirical data is needed to better understand both the economies of scale and potential hidden costs associated with interconnected systems
- **Costs are highly sensitive to existing and proposed system configurations.**
  - The cost of conversion will vary based on type of existing heating and cooling systems.
  - Although retaining existing systems avoids the up-front cost of conversion, they fail to realize the long-term benefits of reduced energy costs.
- **Adding more customers would decrease GSHP rates and improve payback.**
  - A larger customer base would help decrease GSHP heating/cooling rates, further reducing customer energy costs.
  - Increased diversity would improve GSHP performance and reduce or eliminate costs associated with backup heating and cooling systems.

Annual GHG Emissions: GCHP Closed Vertical

Medium Density Mixed-Use

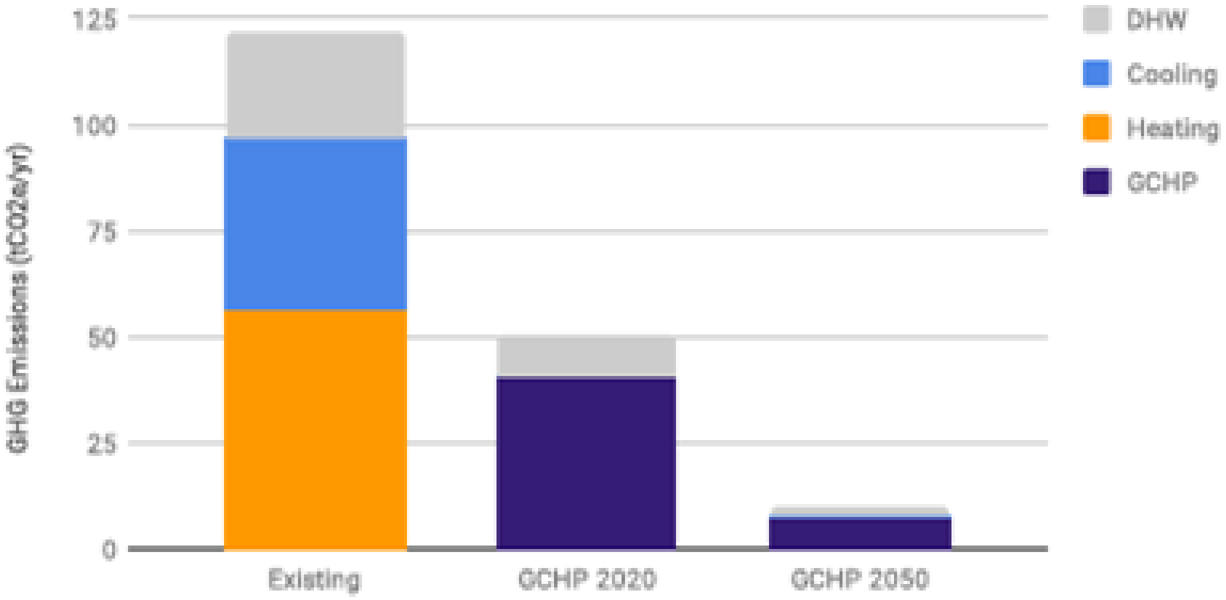


Figure V-2: Medium Density Mixed-Use GHG emissions from heating, cooling, and DHW

Benefits

- Provides long-term thermal storage
- Cuts summer electric grid peaks
- Adapts to changing climate
- Integrates into planned utility corridors
- Provides resilience locally and system wide
- Equitable access to renewable energy

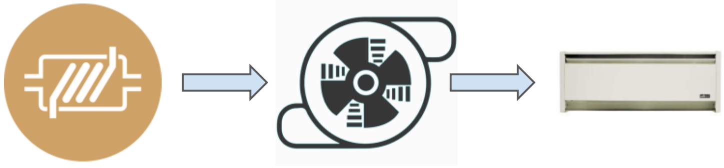
COFFEE BREAK !!!

How would it work in my home?

Just water is in the pipe.

Heat Exchanger

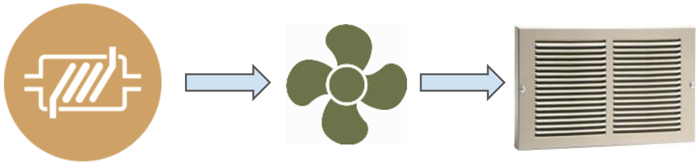
Connects to your existing system



Heat exchanger

Water pump

Radiator

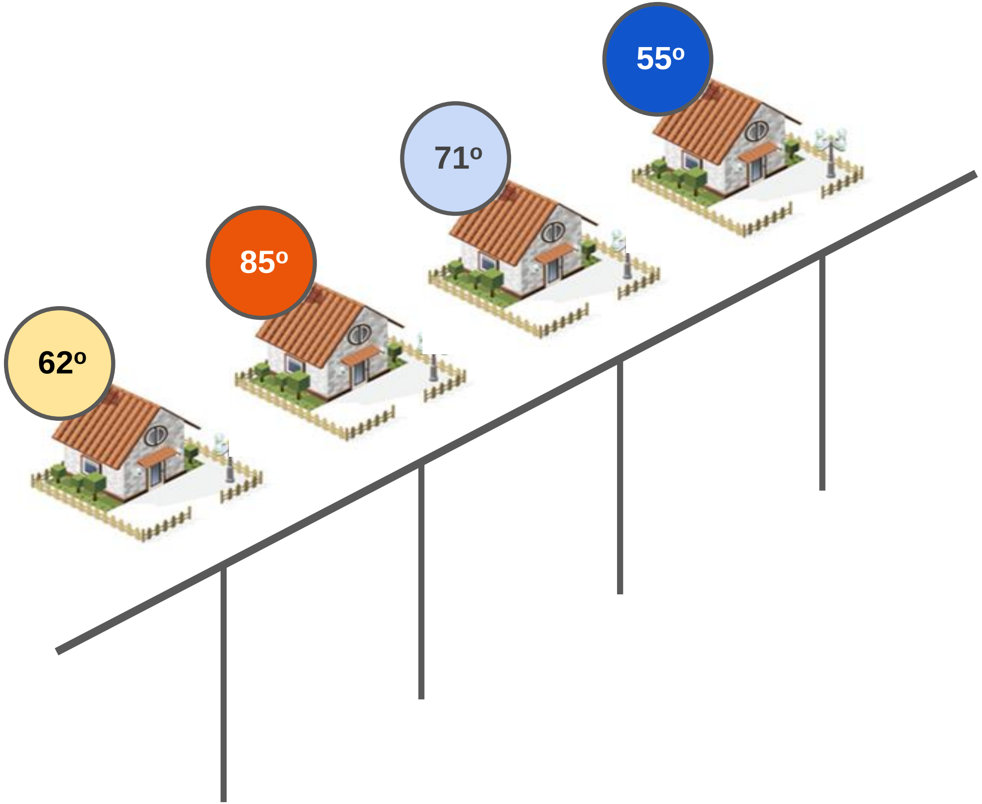


Heat exchanger

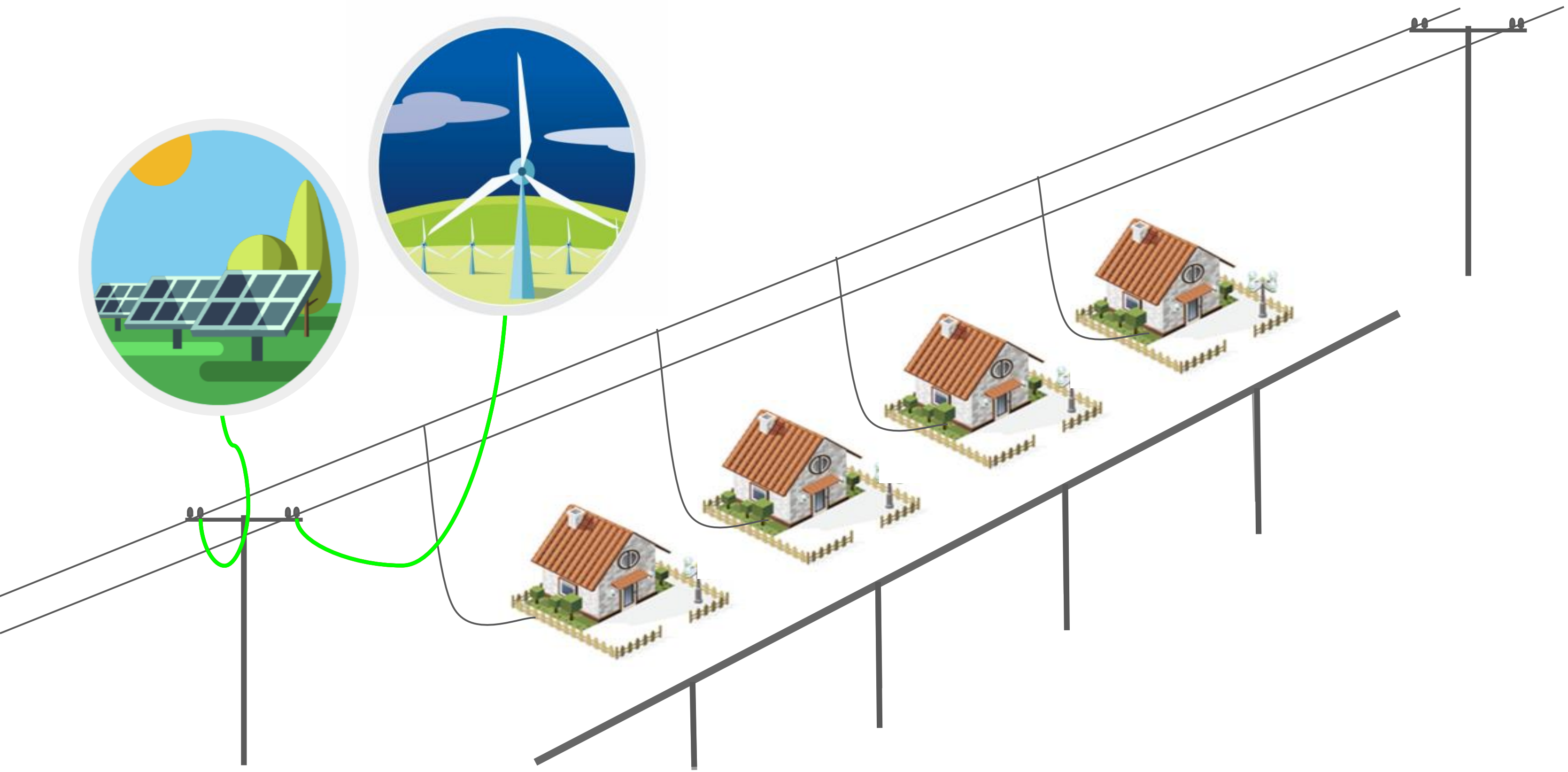
Air handler

Vent

Heat Exchange



Emissions Decrease Over Time



This is Not just a Technical Problem

ENVIRONMENTAL:

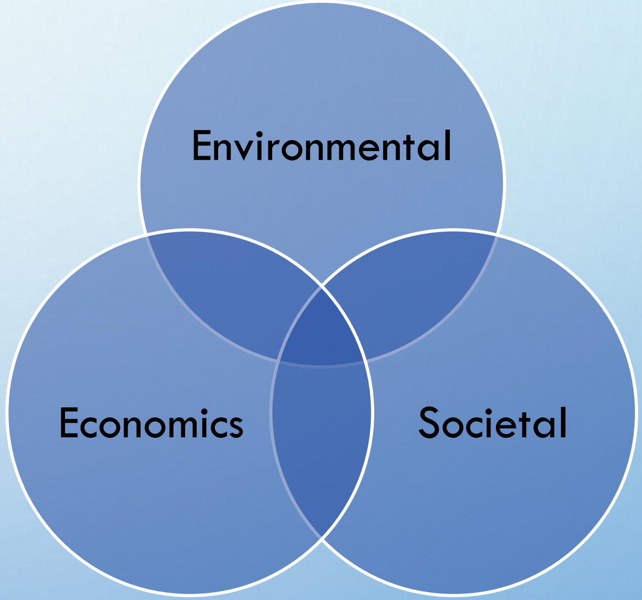
- **GHG Emissions Footprint**
- **Personal Comfort**

ECONOMICS:

- **Performance**
- **First Cost**
- **Life Cycle Cost**
- **Revenue**
- **Replacement Profile**
- **Demand Management**

SOCIETAL:

- **Sustainability**
- **Impact on Future Generations**



WHAT IS THE SCOPE/OBJECTIVE

Ignore It, Fix It, Or Change It
Dirty, Wasteful, and Expensive Vs Clean, Efficient, And Less Expensive

Demonstrate Options To Accomplish The Energy Shift
Suggest A Shift Of Focus And The List Of Solutions
Demonstrate The Feasibility Of The Solutions
Transform The Current Conditions To Enable Implementation Of The Solution
Identify The Costs Of The Solution
Identify The Benefits
Identify Project Owners And Explore A Dual Utility Solution
Define Owners Of The Project Activities
Can A New Paradigm Be Implemented Without Consumer Incentives

Advent of the Thermal Utility without local combustion

NON-COMBUSTION SOLUTIONS

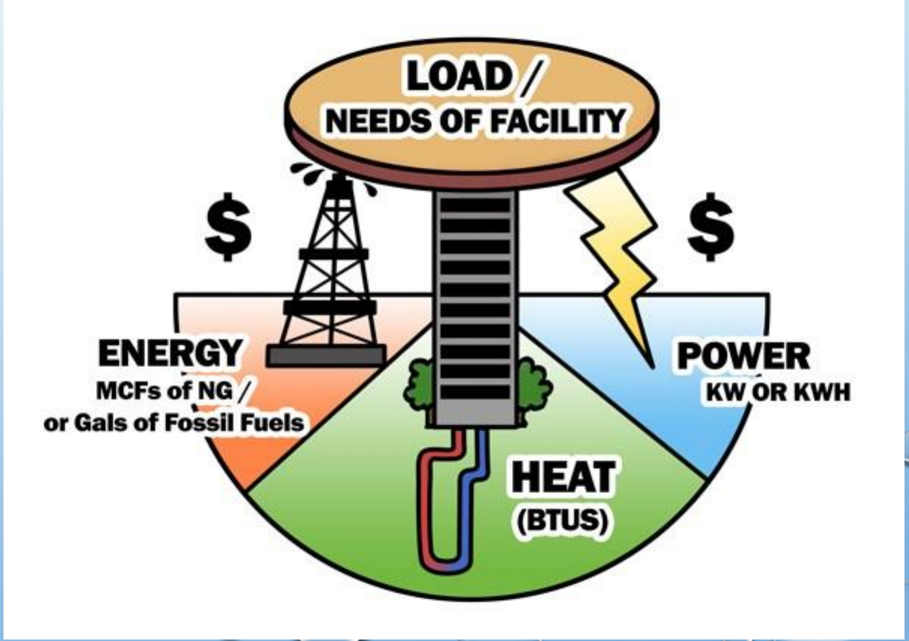
Available Mature Tools

- Use of the affinity laws to our advantage
- Use Temperate Zone Weather to our advantage
- Use Part-Load Design to optimize strategy.
- Use an ambient temperature loop (Heat Pumps Sweet Spot)
- Use The Ground Loop for Thermal Storage, Short and Long Term
- Meld the technologies together; right place, right time, right size
- Add Solar Thermal to the Mix
- Thermal Storage – Salt, Phase Change Materials, boreholes
- Quantify the contribution and positioning of those assets
- Recover use and re-use wasted Energy

THE THERMAL HIGHWAY Storage and Distribution

ENERGY / SHIFT (HEET)

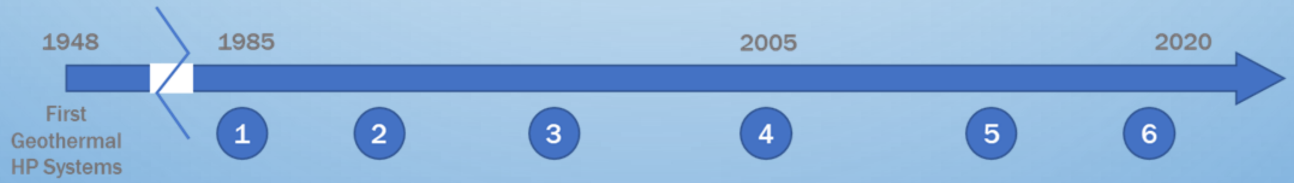
As part of the transition between Heat, Energy, and Power, a common denominator is needed to evaluate efficiency and effectiveness; possibly iCOP$_{kW}$$^{©}$ (TGEG).



THE STAGES OF DEVELOPMENT FROM GROUND SOURCE TO THE THERMAL HIGHWAY

ENERGY SHIFT

1. SINGLE FAMILY WITH BACK UP HEATING
2. SINGLE FAMILY, LIGHT COMMERCIAL AND MULTI-FAMILY
3. SHARED COMMON LOOP AND MULTIPLE HVAC/R UNITS
4. OVERLAYING CONVENTIONAL CENTRAL PLANT OR FOUR PIPE SYSTEMS
5. CONVERTING A CENTRAL PLANT TO A CENTRAL LOOP
6. THE THERMAL HIGHWAY A COMMON CONVECTIVE CIRCULATION CIRCUIT
7. HEAT GRID – MULTIPLE INTEGRATED THERMAL HIGHWAY SYSTEMS



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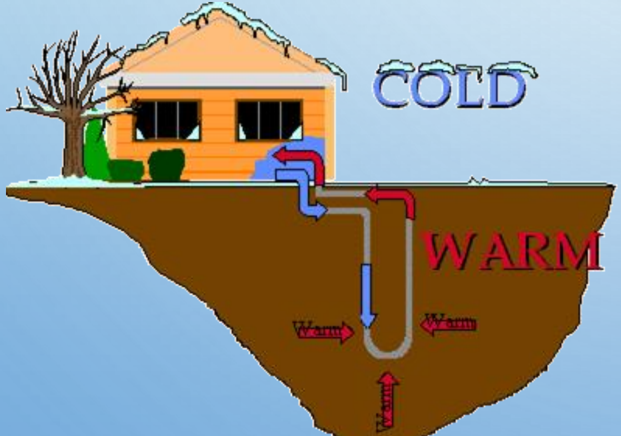
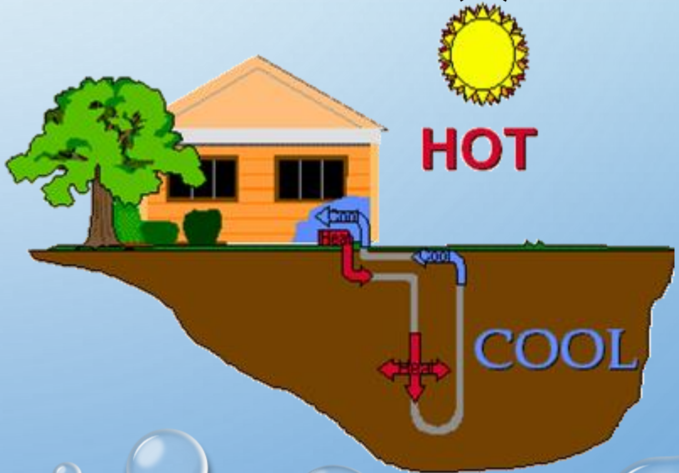
GROUND SOURCE – THE BEGINNING V1.0

SINGLE FAMILY HVAC WITH BACK UP HEATING

- THIS WAS THE MARKET UNTIL IN SITU THERMAL CONDUCTIVITY TESTING WAS DEVELOPED TO BRING IN COMMERCIAL DESIGN OF GROUND HEAT EXCHANGER (GHEX)
- TRAINING WAS DEVELOPED KNOWN AS THE ACCREDITED INSTALLER (AI).



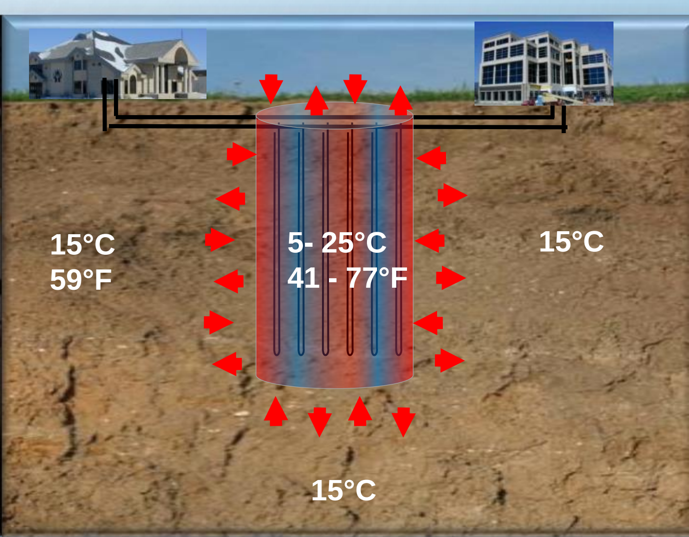


GROUND SOURCE V2.0

- SINGLE FAMILY, LIGHT COMMERCIAL, AND MULTI-FAMILY FACILITIES
  - SPECIAL APPLICATIONS OF RESIDENTIAL AND LIGHT COMMERCIAL TEST
  - GENERALLY A & B USING LIGHT DESIGN SOFTWARE AND C MIGHT REQUIRE COMMERCIAL SOFTWARE
  - TRAINING DEVELOPED KNOWN AS THE CERTIFIED RESIDENTIAL DESIGNER (CRD).
  - RESIDENTIAL AND LIGHT COMMERCIAL (UNDER 30 TON HVAC/R) GENERALLY **NO TEST IN SITU.**
  - NOT USUALLY HYBRID.

Hybrids and Shared Building Loads - V3.0

Some projects present opportunities to transfer energy from one building to another. “Waste” energy rejected to atmosphere from an ice rink refrigeration plant can be redirected to GHX connected to nearby swimming pool. Both benefit from more moderate GHX temperature and a lower capital cost of constructing the system.



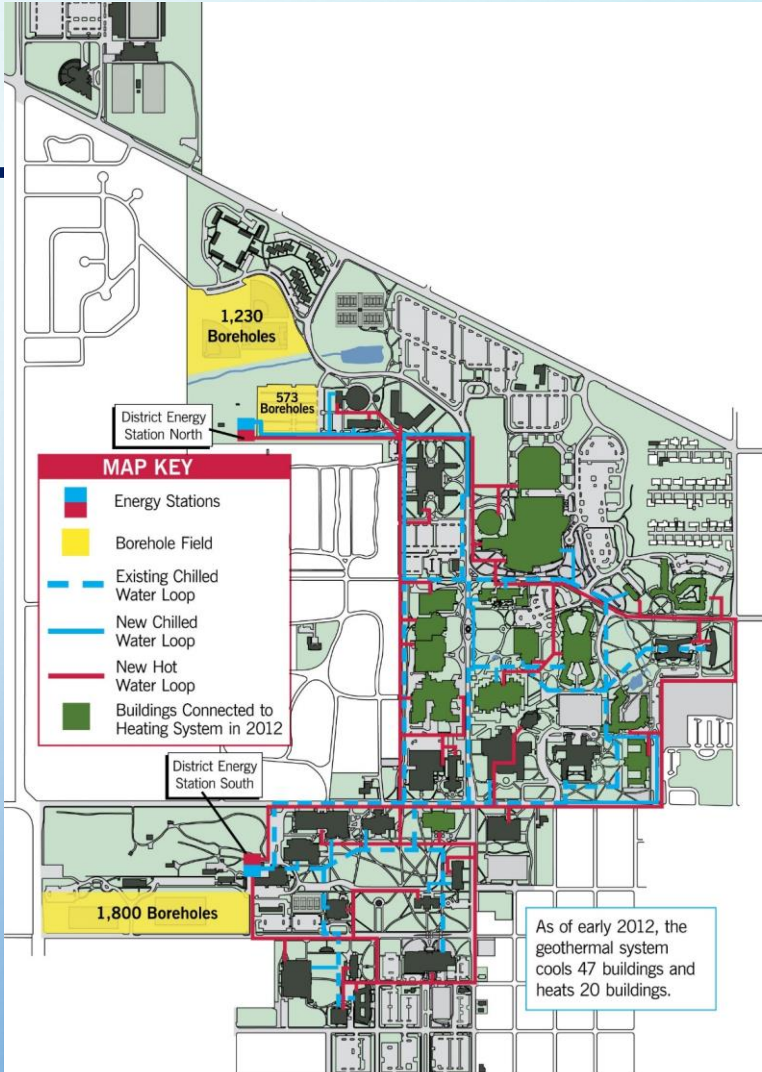
A DEAD-END RABBIT HOLE V4.0 - TROUBLE

A Central Loop as a simple over-lay to an existing system.

- Designing a central loop as a primary or an add-on to a conventional system – least efficient way for a Thermal Highway.
- Locks the user into the worst of both systems.
- Building loads are “full size” and GXHE is full size because the conventional system is taking peak load(s).

BALL STATE UNIVERSITY V5.0

- HOT AND COLD WATER IS ROUTED THROUGHOUT THE CAMPUS VIA TWO SEPARATE DISTRICT LOOPS, *BUILDING INTERFACE*
- THE DISTRICT LOOPS SUPPLY BUILDINGS' DEMAND FOR HEATING OR COOLING.
- HEAT PUMPS MAYBE EMPLOYED IN LIMITED APPLICATIONS **BUT GENERALLY DO NOT SHARE WITH THE CENTRAL PLANT SYSTEM THE WASTED ENERGY FROM THE SATELLITE BUILDING(S).** IF ENERGY IS SHARED, IT IS FROM THE CHILLED WATER RETURN LOOP.


1,230 Boreholes
573 Boreholes
District Energy Station North
MAP KEY
Energy Stations
Borehole Field
Existing Chilled Water Loop
New Chilled Water Loop
New Hot Water Loop
Buildings Connected to Heating System in 2012
District Energy Station South
1,800 Boreholes

As of early 2012, the geothermal system cools 47 buildings and heats 20 buildings.

The Thermal Highway Concept

GreyEdge Group

Energy *harvested*, *moved*, and *reused*

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gsexton@greyedgegroup.com
csmith@greyedgegroup.com

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DESIGNING FOR BALANCE

TM – Energy Highway is a trademark of Sound Geothermal Corporation

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KEY TAKEAWAYS

1. SHARE PROVEN METHODS TO UTILIZE MULTIPLE THERMAL ASSETS TO OPTIMIZE SITE OR CAMPUS ENERGY.

   - HARVEST IT, STORE IT, SHARE IT, USE IT.

2. HEAT PUMP SYSTEMS MAKE *SENSE* AND *CENTS*!
3. GEO HEAT PUMP SYSTEMS ADD TO SYSTEM VERSATILITY.

Primary Considerations

Heat Pump efficiency is significantly influenced by entering water **temperature** and **flow rate**…

Keep the heat pumps happy!

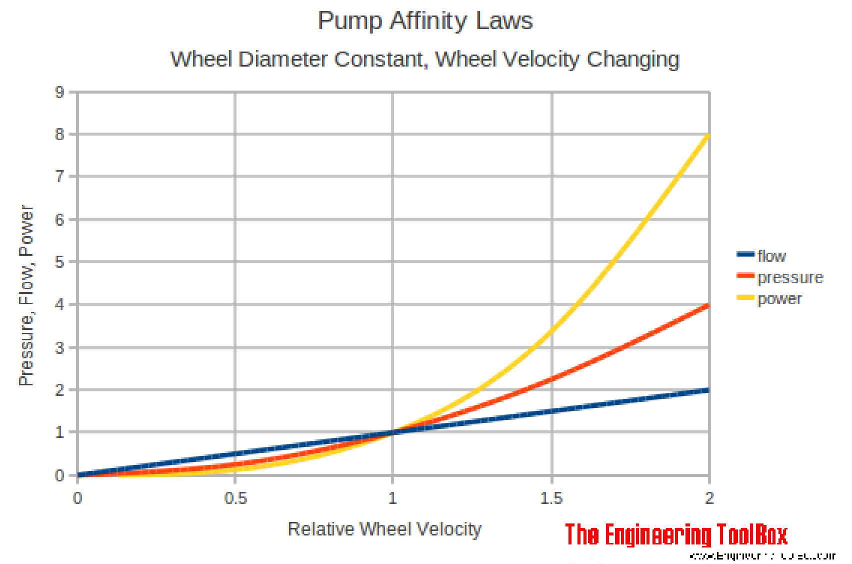
AFFINITY LAWS FOR DUMMIES

THE **AFFINITY LAWS** (ALSO KNOWN AS THE "FAN LAWS" OR "PUMP LAWS") FOR PUMPS/FANS ARE USED IN HYDRAULICS, HYDRONICS AND/OR HVAC TO EXPRESS THE RELATIONSHIP BETWEEN VARIABLES INVOLVED IN PUMP OR FAN PERFORMANCE (I.E. HEAD, VOLUMETRIC FLOW RATE,) AND POWER.

Full Speed - Full Flow - Full Pressure – Full Energy Consumption

Half Speed – Half Flow – **¼ Pressure – 1/8 Power**

Pumping cost is forever…



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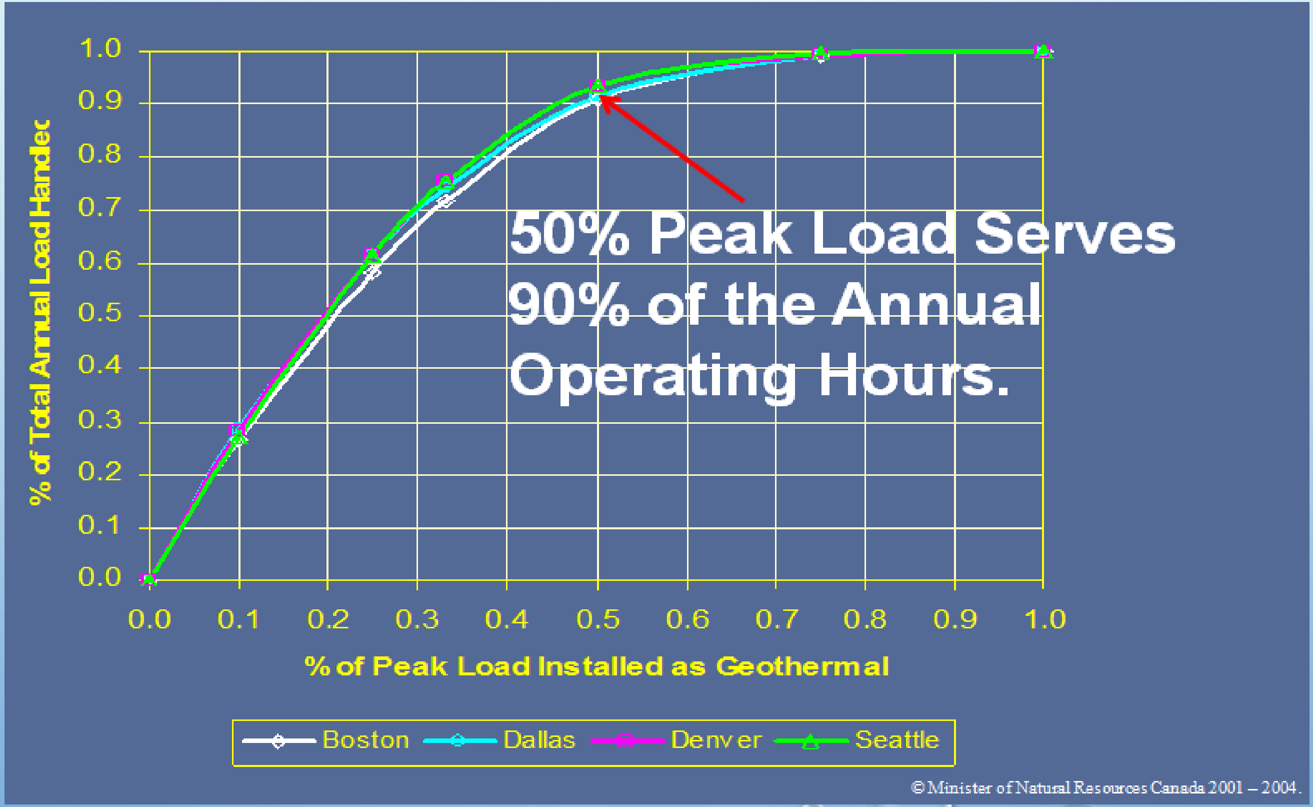
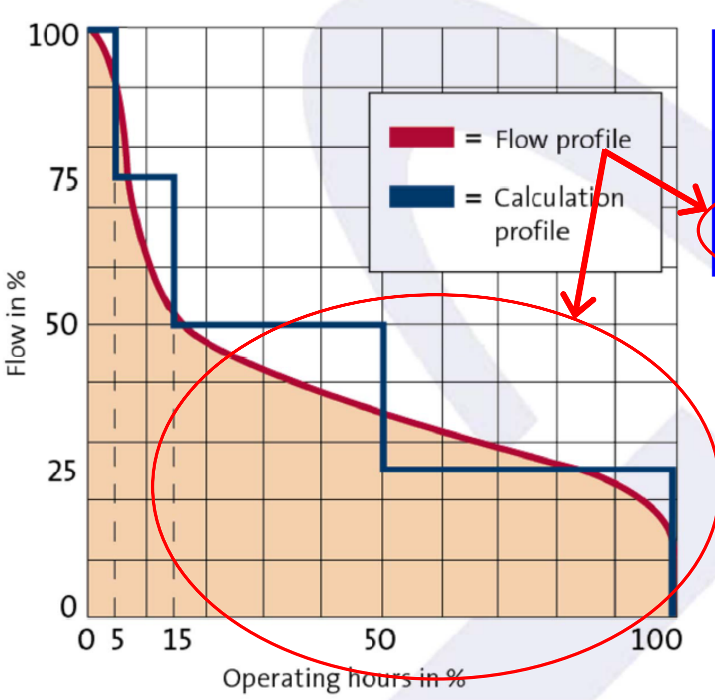
% OF PEAK LOAD VS. % OF ANNUAL HOURS OCCURRENCE – “50/90 RULE”



50% Peak Load Serves 90% of the Annual Operating Hours.

© Minister of Natural Resources Canada 2001 – 2004.

BLAUER ENGLE PROFILE (GERMAN/EUROPEAN E-STAR)… USING THE AFFINITY LAWS



Flow in %	Hours in %
100	6
75	15
50	35
25	44

This profile is also applicable to the building load.

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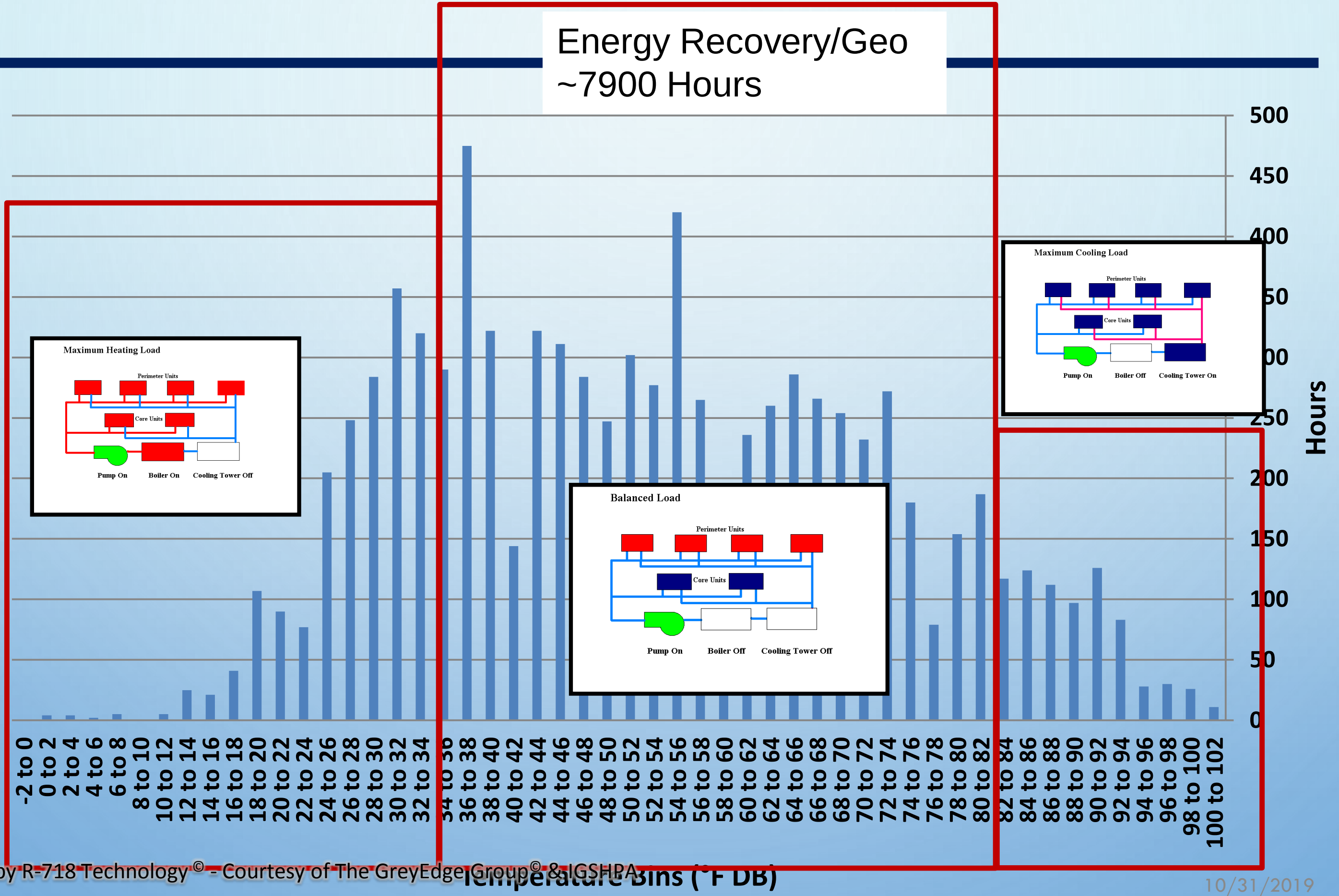
Bin Data - Salt Lake City, UT – 8760



Energy Recovery/Geo
~7900 Hours

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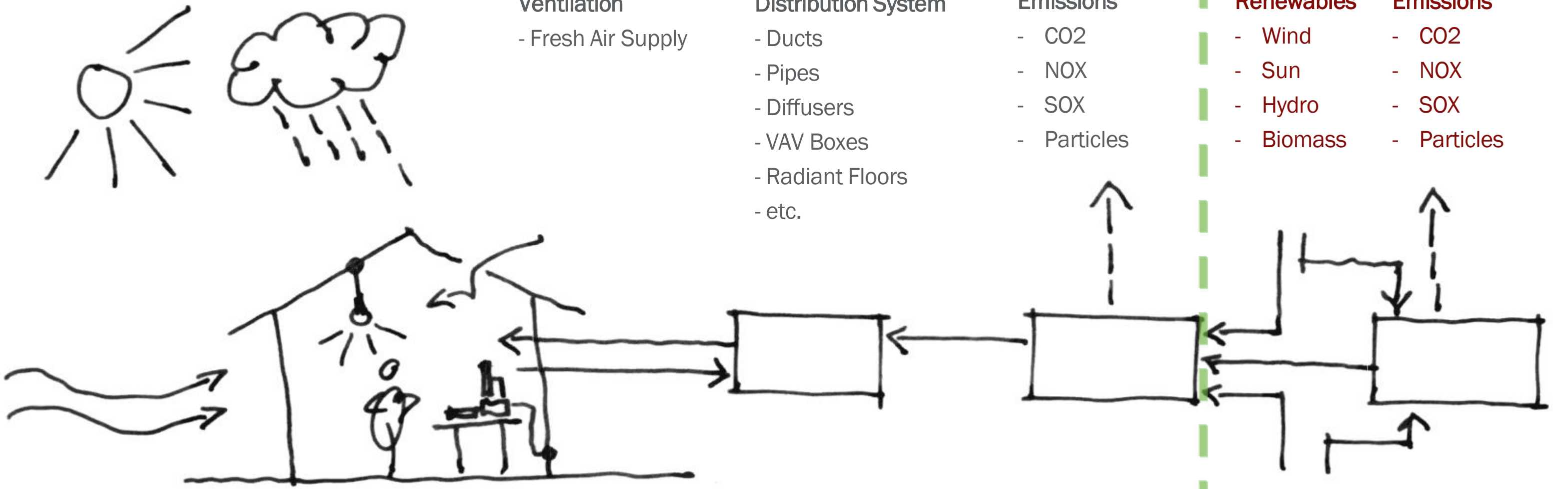
Dynamic hourly (8760 hours) energy simulation



Site

Ventilation
- Fresh Air Supply

Distribution System
- Ducts
- Pipes
- Diffusers
- VAV Boxes
- Radiant Floors
- etc.

Emissions
- CO2
- NOX
- SOX
- Particles

Climate
- Air Temperature
- Solar Radiation
- Rain
- Wind
- etc.

Individual
- Clothing
- Activity level
- Comfort Criteria

Enclosure
- Walls
- Windows
- Roof

Conditioning Systems
- Chillers
- Heat Pumps
- Air Handling Units
- Fans
- Pumps
- etc.

Energy Systems
- Boilers
- Transformers
- Cooling Towers
- Generators
- PV's
- Windturbines

Source

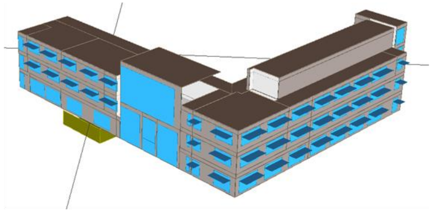
Renewables
- Wind
- Sun
- Hydro
- Biomass

Emissions
- CO2
- NOX
- SOX
- Particles

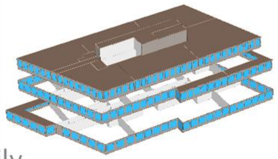
Fossil Fuels
- Gas
- Oil
- Diesel
- Coal

Utility Infrastructure
- Powerplants
- Steam Plants
- District Energy Plants

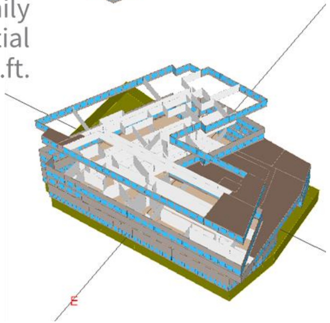
Typical use for Dynamic Energy Models



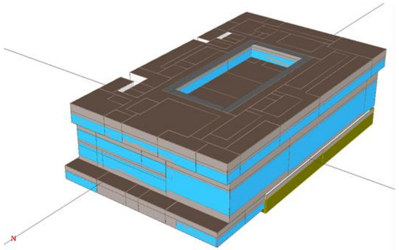
Academic Science Lab - 41,000 sq.ft.



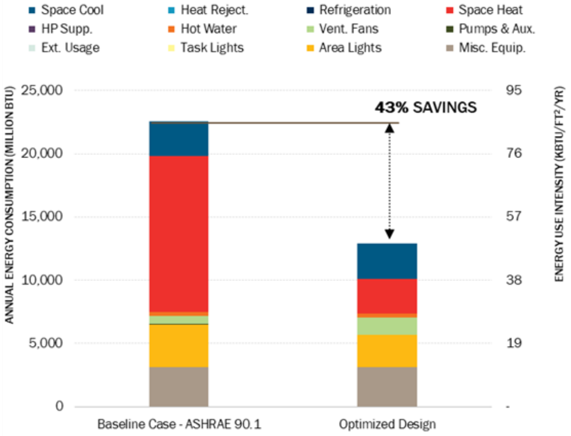
Multifamily Residential 491,000 sq.ft.



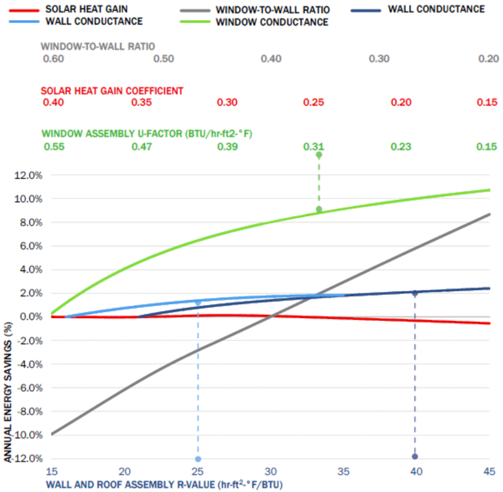
Academic Mixed-Use 107,000 sq.ft.



Comparative studies show relative performance against a Baseline Case



Sensitivity studies inform optimal design performance



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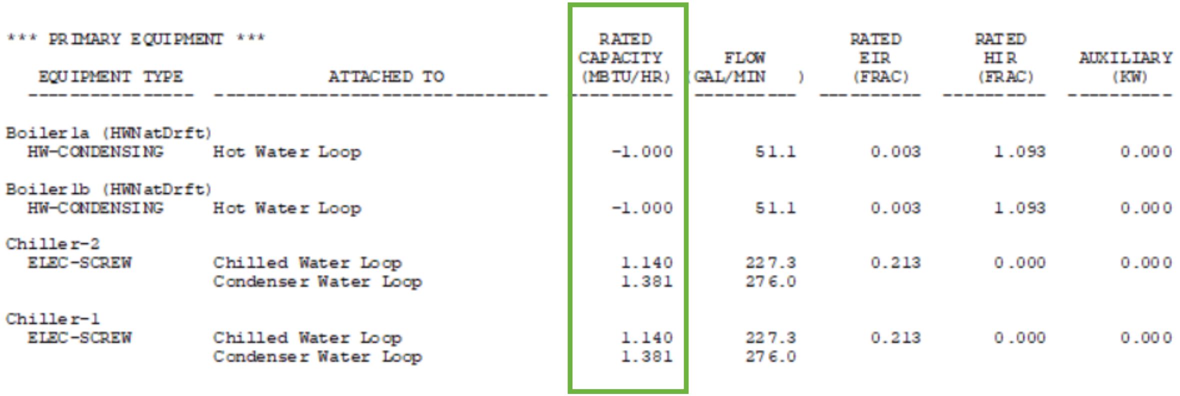
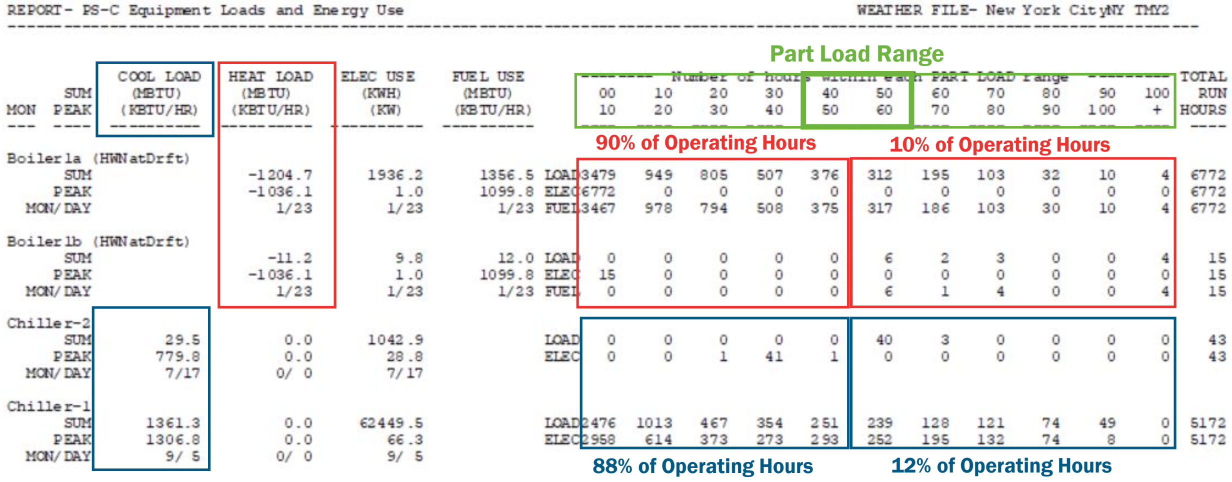
Coincident Loads versus Peak Loads

Design Peak
Equipment sizing:



```
*** PRIMARY EQUIPMENT ***                                          RATED                     RATED      RATED
                                                                 CAPACITY     FLOW          EIR        HIR       AUXILIARY
   EQUIPMENT TYPE            ATTACHED TO                         (MBTU/HR)  (GAL/MIN  )    (FRAC)     (FRAC)       (KW)
  ---------------   ---------------------------------------    ----------  ----------   ---------  ---------   ---------

Boiler1a (HWNatDrft)
  HW-CONDENSING     Hot Water Loop                                -1.000        51.1        0.003      1.093       0.000

Boiler1b (HWNatDrft)
  HW-CONDENSING     Hot Water Loop                                -1.000        51.1        0.003      1.093       0.000

Chiller-2
  ELEC-SCREW        Chilled Water Loop                             1.140       227.3        0.213      0.000       0.000
                    Condenser Water Loop                           1.381       276.0

Chiller-1
  ELEC-SCREW        Chilled Water Loop                             1.140       227.3        0.213      0.000       0.000
                    Condenser Water Loop                           1.381       276.0
```

Actual Operation:



```
REPORT- PS-C Equipment Loads and Energy Use                                          WEATHER FILE- New York CityNY TMY2
------------------------------------------------------------------------------------------------------------------------

                COOL LOAD   HEAT LOAD   ELEC USE    FUEL USE    --------- Number of hours within each PART LOAD range ---------  TOTAL
       SUM       (MBTU)      (MBTU)      (KWH)       (MBTU)         00    10    20    30    40    50    60    70    80    90   100    RUN
MON   PEAK     (KBTU/HR)   (KBTU/HR)     (KW)      (KBTU/HR)        10    20    30    40    50    60    70    80    90   100     +  HOURS
---   ----    ----------  ----------  ----------  ----------                                                                      ----

Boiler1a (HWNatDrft)
       SUM                    -1204.7      1936.2      1356.5  LOAD3479   949   805   507   376   312   195   103    32    10     4   6772
      PEAK                    -1036.1         1.0      1099.8  ELEC6772     0     0     0     0     0     0     0     0     0     0   6772
   MON/DAY                       1/23        1/23        1/23  FUEL3467   978   794   508   375   317   186   103    30    10     4   6772

Boiler1b (HWNatDrft)
       SUM                      -11.2         9.8        12.0  LOAD   0     0     0     0     0     6     2     3     0     0     4     15
      PEAK                    -1036.1         1.0      1099.8  ELEC  15     0     0     0     0     0     0     0     0     0     0     15
   MON/DAY                       1/23        1/23        1/23  FUEL   0     0     0     0     0     6     1     4     0     0     4     15

Chiller-2
       SUM          29.5          0.0      1042.9              LOAD   0     0     0     0     0    40     3     0     0     0     0     43
      PEAK         779.8          0.0        28.8              ELEC   0     0     1    41     1     0     0     0     0     0     0     43
   MON/DAY          7/17         0/ 0        7/17

Chiller-1
       SUM        1361.3          0.0     62449.5              LOAD2476  1013   467   354   251   239   128   121    74    49     0   5172
      PEAK        1306.8          0.0        66.3              ELEC2958   614   373   273   293   252   195   132    74     8     0   5172
   MON/DAY          9/ 5         0/ 0        9/ 5
```

Part Load Range

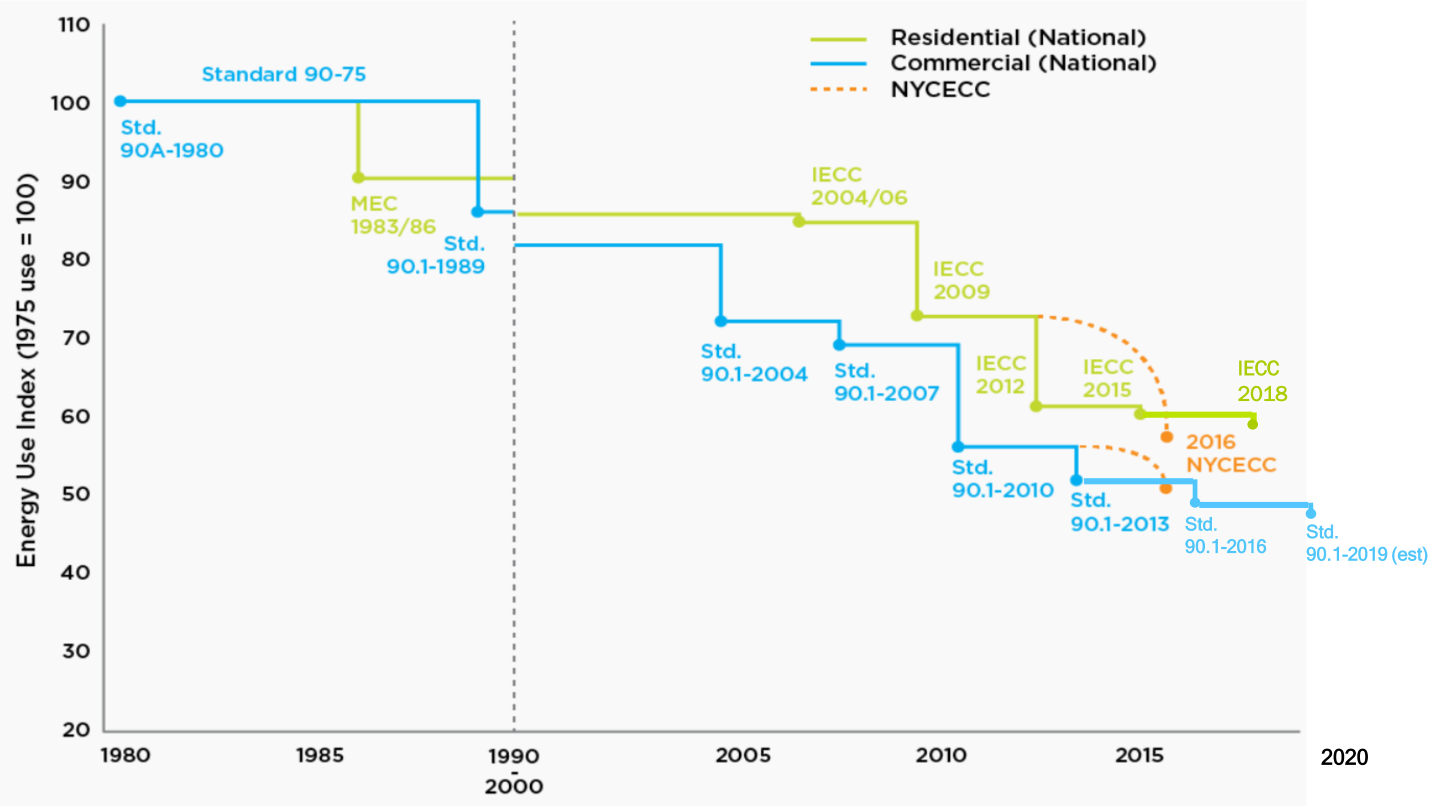
90% of Operating Hours

10% of Operating Hours

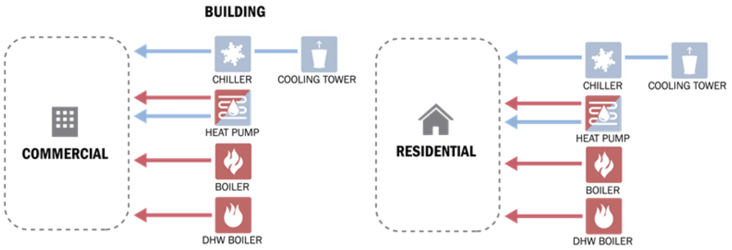
88% of Operating Hours

12% of Operating Hours

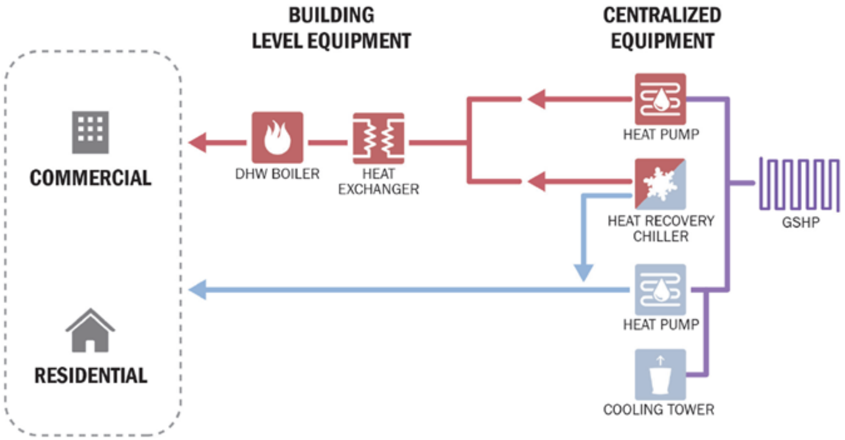
Current Building Energy Codes in United States



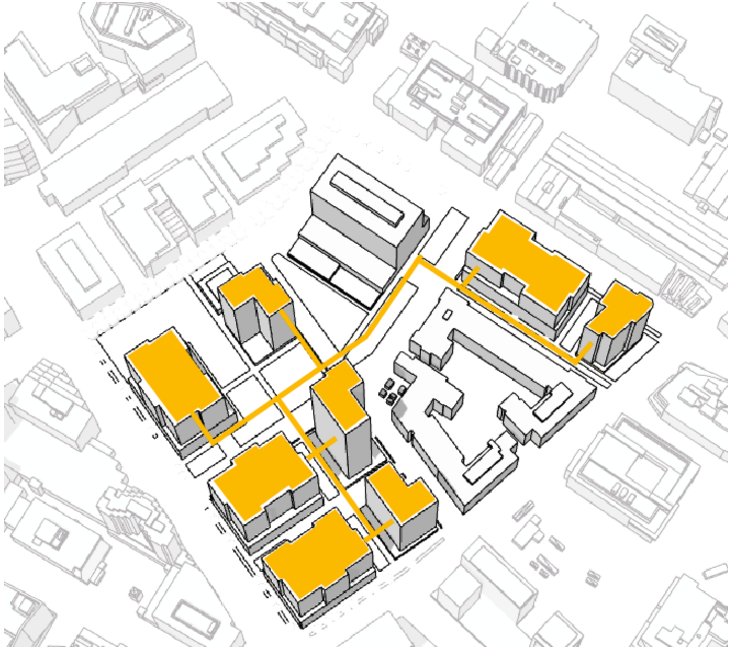
Net Zero Development – What infrastructure do we need to plan for?


BUILDING
COMMERCIAL
CHILLER
COOLING TOWER
HEAT PUMP
BOILER
DHW BOILER
RESIDENTIAL
CHILLER
COOLING TOWER
HEAT PUMP
BOILER
DHW BOILER

Stand-alone


BUILDING LEVEL EQUIPMENT
CENTRALIZED EQUIPMENT
COMMERCIAL
RESIDENTIAL
DHW BOILER
HEAT EXCHANGER
HEAT PUMP
HEAT RECOVERY CHILLER
GSHP
HEAT PUMP
COOLING TOWER

District



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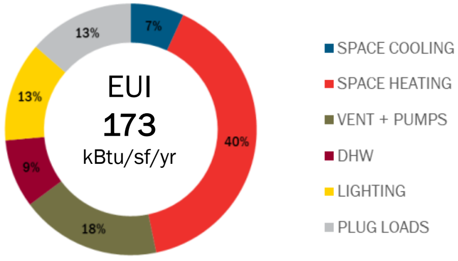
Meeting Net Zero Goals requires Parametric Hourly Load Analysis

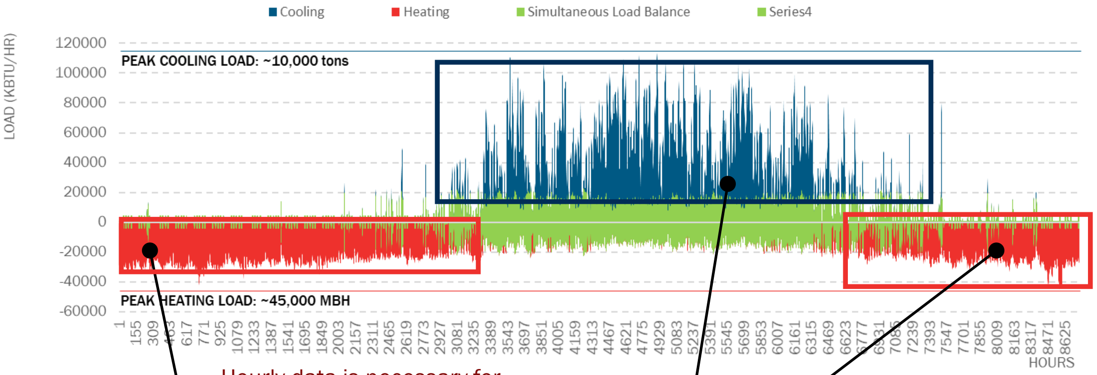
ANNUAL ENERGY END USE CHARACTERIZATION



100% Lab

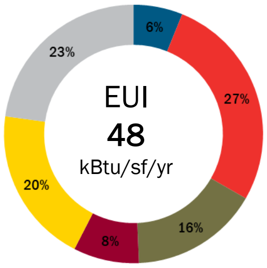
HEATING AND COOLING LOAD PROFILE

9771 VOLPE MASTERPLAN



Hourly data is necessary for understanding seasonal heating and cooling load balance

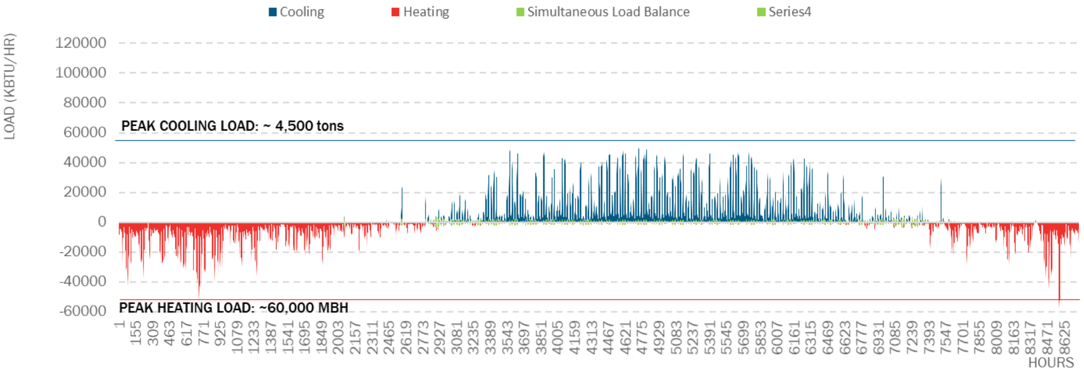
ANNUAL ENERGY END USE CHARACTERIZATION



100% Office

HEATING AND COOLING LOAD PROFILE

9771 VOLPE MASTERPLAN



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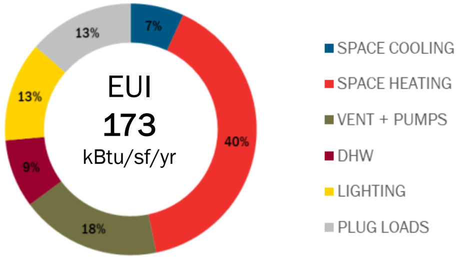
Meeting Net Zero Goals requires Parametric Hourly Load Analysis

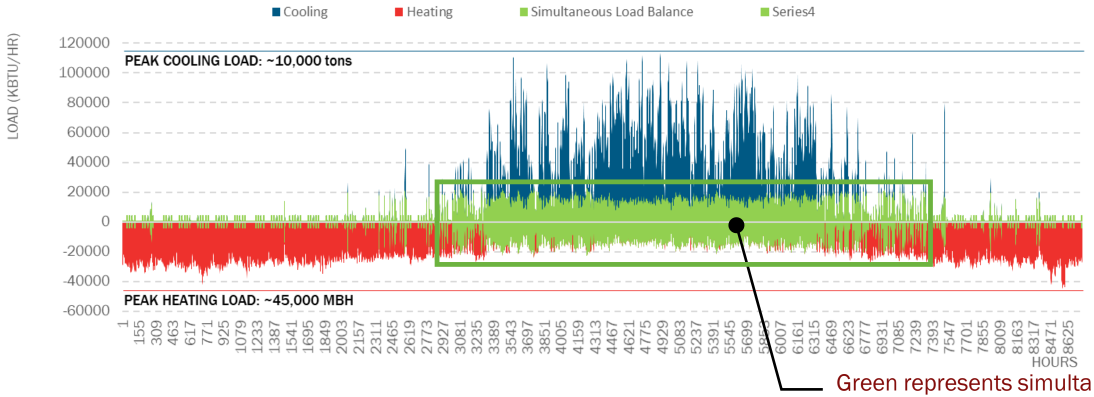
ANNUAL ENERGY END USE CHARACTERIZATION



100% Lab

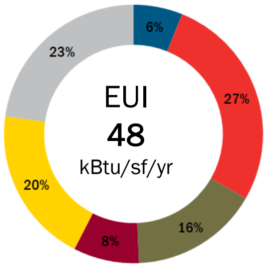
HEATING AND COOLING LOAD PROFILE

9771 VOLPE MASTERPLAN



Green represents simultaneous heating and cooling, an opportunity for the most efficient application of heat pumps

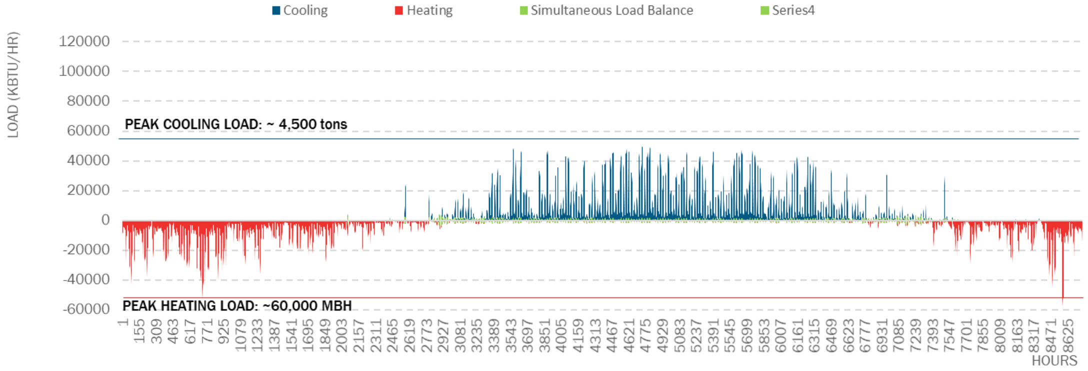
ANNUAL ENERGY END USE CHARACTERIZATION



100% Office

HEATING AND COOLING LOAD PROFILE

9771 VOLPE MASTERPLAN



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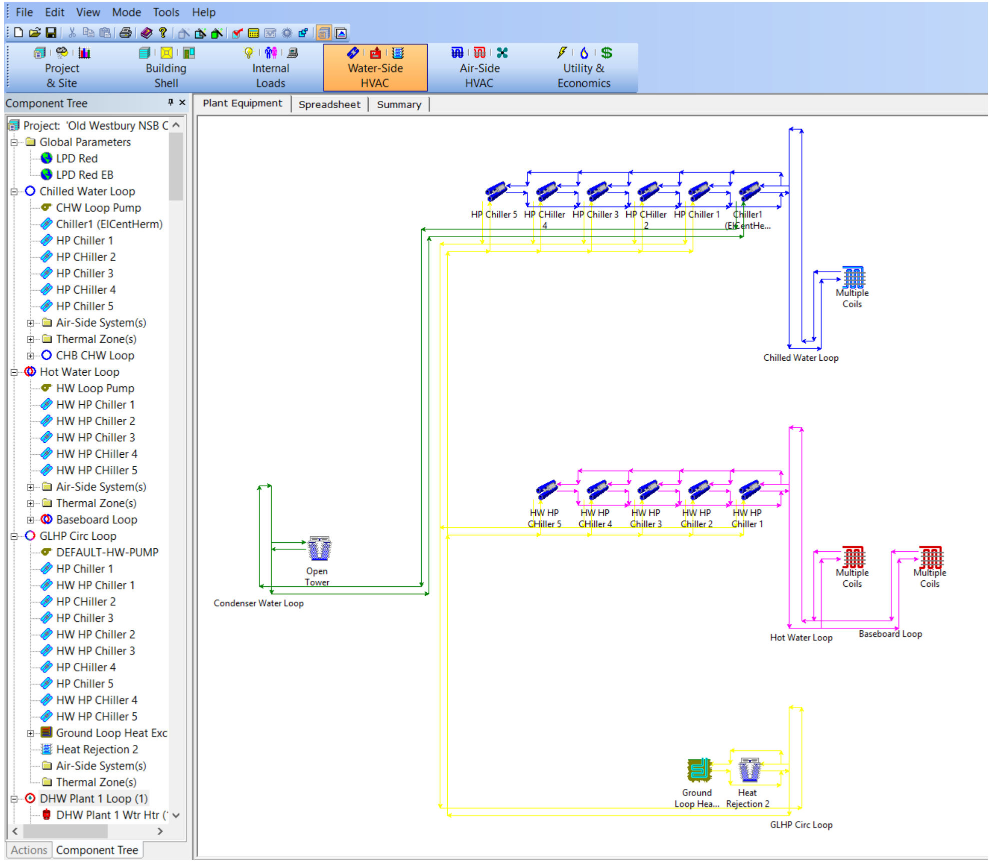
Dynamic Simulation of Buildings and Building Systems

Which Simulation Tool is right for studying the Thermal Highway?



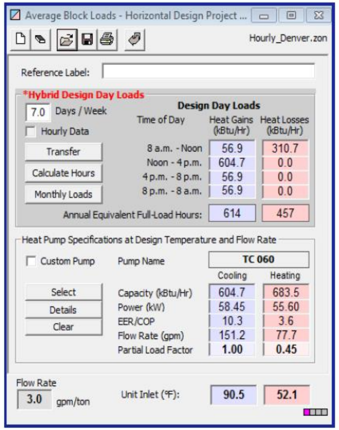
Building Simulation Tools

- eQUEST
- Energy Plus
- IES
- Trane Trace
- Carrier HAP
- Bentley

These tools are all designed to simulate buildings and their systems. Some of these tools have capabilities to simulate ground loop heat exchangers but the capabilities are limited.

Dynamic Simulation of Ground Heat Exchange Loops

Which Simulation Tool is right for studying the Thermal Highway?



Reference Label:

*Hybrid Design Day Loads

7.0 Days / Week

☐ Hourly Data

Design Day Loads

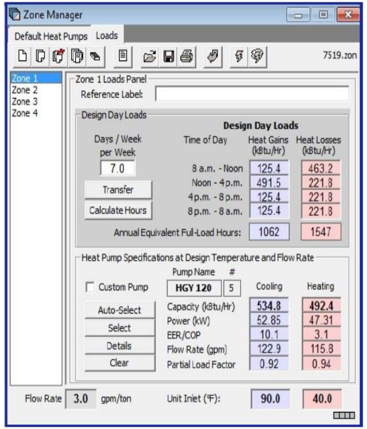
Time of Day	Heat Gains (kBtu/Hr)	Heat Losses (kBtu/Hr)
8 a.m. - Noon	56.9	310.7
Noon - 4 p.m.	604.7	0.0
4 p.m. - 8 p.m.	56.9	0.0
8 p.m. - 8 a.m.	56.9	0.0
Annual Equivalent Full-Load Hours:	614	457

Heat Pump Specifications at Design Temperature and Flow Rate

☐ Custom Pump   Pump Name: TC 060

	Cooling	Heating
Capacity (kBtu/Hr)	604.7	683.5
Power (kW)	58.45	55.60
EER/COP	10.3	3.6
Flow Rate (gpm)	151.2	77.7
Partial Load Factor	1.00	0.45

Flow Rate: 3.0 gpm/ton   Unit Inlet (°F): 90.5   52.1



Zone 1 Loads Panel

Reference Label:

Design Day Loads

Days / Week: 7.0

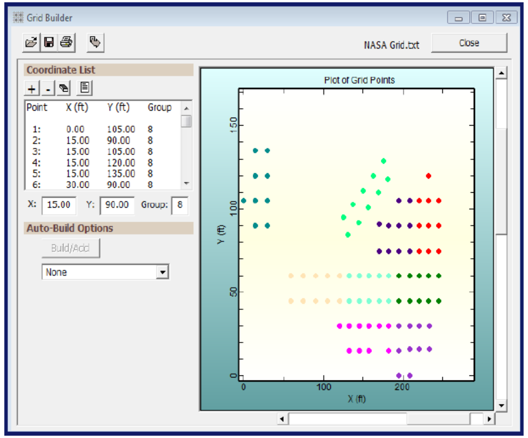
Time of Day	Heat Gains (kBtu/Hr)	Heat Losses (kBtu/Hr)
8 a.m. - Noon	125.4	463.2
Noon - 4 p.m.	491.5	221.8
4 p.m. - 8 p.m.	125.4	221.8
8 p.m. - 8 a.m.	125.4	221.8
Annual Equivalent Full-Load Hours:	1062	1547

Heat Pump Specifications at Design Temperature and Flow Rate

☐ Custom Pump   Pump Name: HGY 120   #: 5

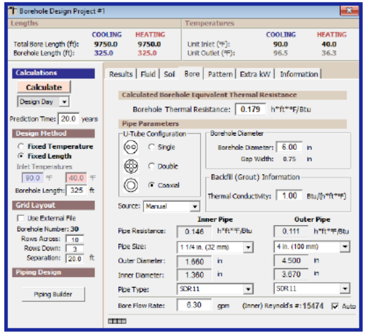
	Cooling	Heating
Capacity (kBtu/Hr)	534.8	492.4
Power (kW)	52.85	47.31
EER/COP	10.1	3.1
Flow Rate (gpm)	122.9	115.8
Partial Load Factor	0.92	0.94

Flow Rate: 3.0 gpm/ton   Unit Inlet (°F): 90.0   40.0



Point	X (ft)	Y (ft)	Group
1:	0.00	105.00	8
2:	15.00	90.00	8
3:	15.00	105.00	8
4:	15.00	120.00	8
5:	15.00	135.00	8
6:	30.00	90.00	8

X: 15.00   Y: 90.00   Group: 8



Lengths	COOLING	HEATING
Total Bore Length (ft):	9750.0	9750.0
Borehole Length (ft):	325.0	325.0

Temperatures	COOLING	HEATING
Unit Inlet (°F):	90.0	40.0
Unit Outlet (°F):	96.5	36.3

Prediction Time: 20.0 years

○ Fixed Temperature
● Fixed Length

Calculated Borehole Equivalent Thermal Resistance

Borehole Thermal Resistance: 0.179 h*ft*°F/Btu

Pipe Parameters

Borehole Diameter: 6.00 in   Gap Width: 0.75 in

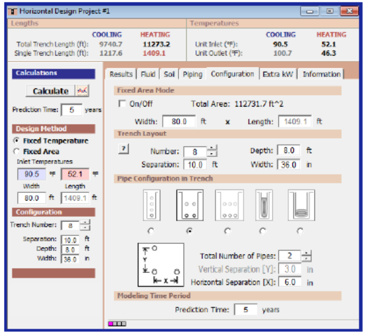
Backfill (Grout) Information   Thermal Conductivity: 1.00 Btu/(h*ft*°F)

Source: Manual

	Inner Pipe	Outer Pipe
Pipe Resistance:	0.146	0.111
Pipe Size:	1 1/4 in. (32 mm)	4 in. (100 mm)
Outer Diameter:	1.660	4.500
Inner Diameter:	1.360	3.870
Pipe Type:	SDR11	SDR11

Bore Flow Rate: 6.30 gpm   (Inner) Reynolds #: 15474   ☑ Auto

Borehole Number: 30



Lengths	COOLING	HEATING
Total Trench Length (ft):	9740.7	11273.2
Single Trench Length (ft):	1217.6	1409.1

Temperatures	COOLING	HEATING
Unit Inlet (°F):	90.5	52.1
Unit Outlet (°F):	100.7	46.3

Prediction Time: 5 years

● Fixed Temperature
○ Fixed Area

Fixed Area Mode: ☐ On/Off   Total Area: 112731.7 ft^2

Width: 80.0 ft × Length: 1409.1 ft

Trench Layout: Number: 8   Depth: 8.0 ft   Separation: 10.0 ft   Width: 36.0 in

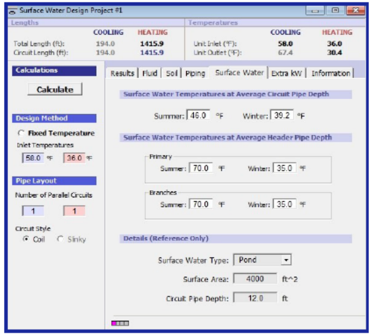
Pipe Configuration in Trench

Total Number of Pipes: 2

Vertical Separation [Y]: 3.0 in

Horizontal Separation [X]: 6.0 in

Modeling Time Period   Prediction Time: 5 years



Lengths	COOLING	HEATING
Total Length (ft):	194.0	1415.9
Circuit Length (ft):	194.0	1415.9

Temperatures	COOLING	HEATING
Unit Inlet (°F):	58.0	36.0
Unit Outlet (°F):	67.4	30.4

Surface Water Temperatures at Average Circuit Pipe Depth: Summer: 46.0 °F   Winter: 39.2 °F

Surface Water Temperatures at Average Header Pipe Depth

Primary: Summer: 70.0 °F   Winter: 35.0 °F

Branches: Summer: 70.0 °F   Winter: 35.0 °F

Details (Reference Only)

Surface Water Type: Pond

Surface Area: 4000 ft^2

Circuit Pipe Depth: 12.0 ft

Number of Parallel Circuits: 1   1

Circuit Style: ● Coil ○ Slinky

Vertical GHX Module   **Horizontal GHX Module**   **Surface Water GHX Module**

Ground Heat Exchange Simulation and Design Tools

- Ground Loop Design
- Loop Link Pro
- GLHE Pro

These tools are all designed to simulate ground loop heat exchanger designs. They have limited capabilities to estimate building loads and almost no capability to simulate HVAC systems other than heat pumps.

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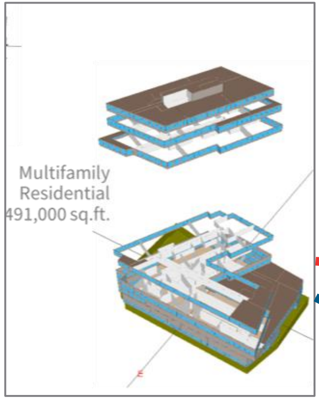
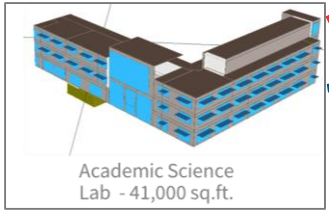
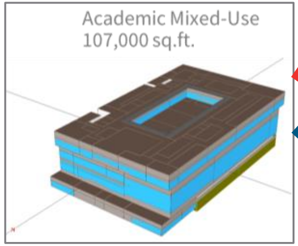
Simulating the Thermal Highway


Multifamily Residential 491,000 sq.ft.

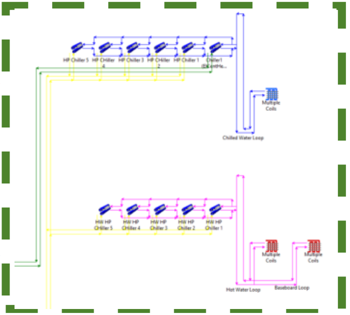

Academic Science Lab - 41,000 sq.ft.


Academic Mixed-Use 107,000 sq.ft.

Individual Building Models

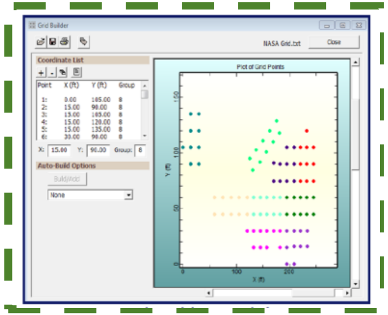
Minimize heating and cooling loads through optimized building systems

Combined, Hourly Heating and Cooling Load Profiles



Central Plant Model

Iterate High Level Design Options



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3:	15.00	105.00	8
4:	15.00	120.00	8
5:	15.00	135.00	8
6:	30.00	90.00	8

X: 15.00 Y: 90.00 Group: 8

Ground Loop Heat Exchanger Design Model-

Optimize final design.

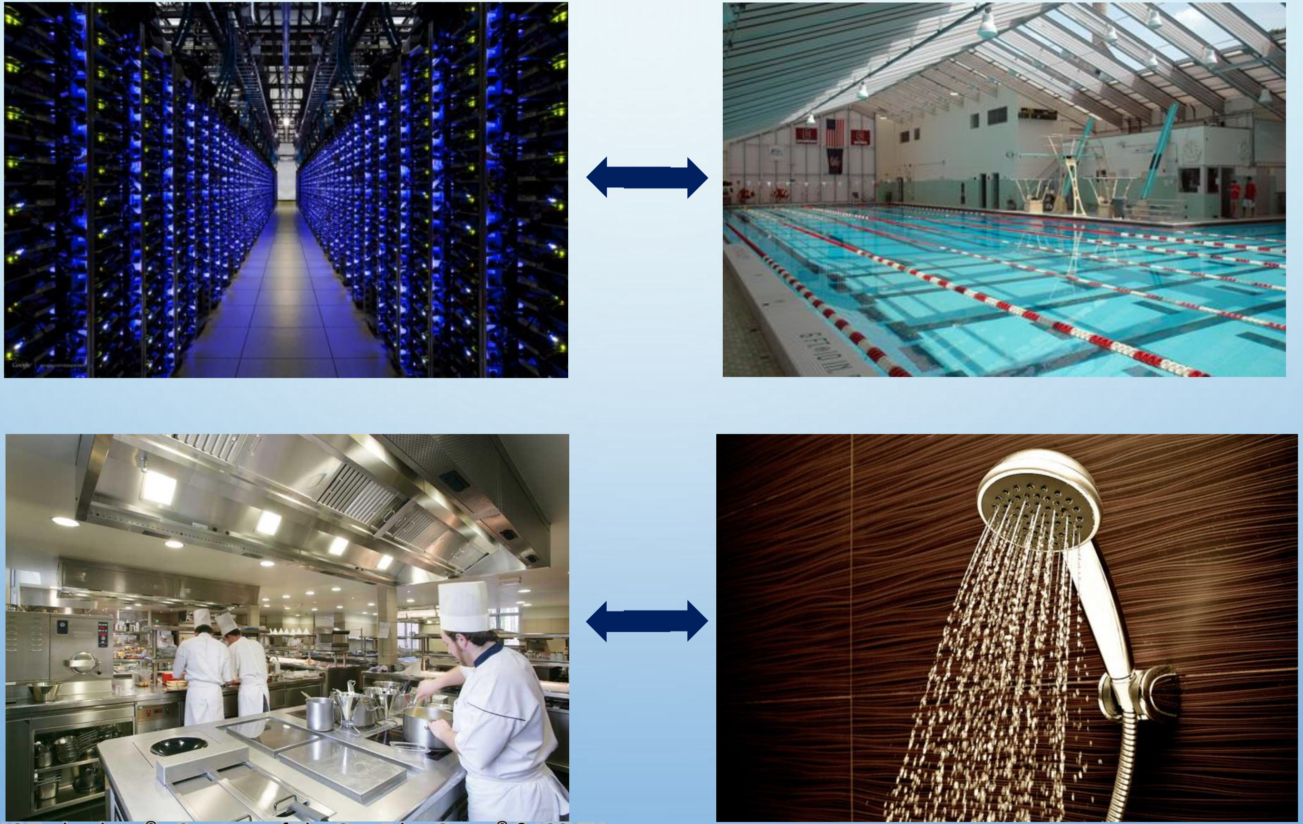
Custom Hourly Models

Optimize final design features.

Ground Source and Wasted Energy Recovery

- Move energy from one building or use to another
- Use the ground for thermal storage
- Store solar thermal energy
- Level energy loads on the system
- Shift system electrical demand peaks
- Shed excess energy at a time of day that is most advantageous
- Store energy to sell to other users – (micro grid applications)
- **Increase the system efficiency to 300% to 600%**

BALANCING ENERGY SOURCES / SINKS



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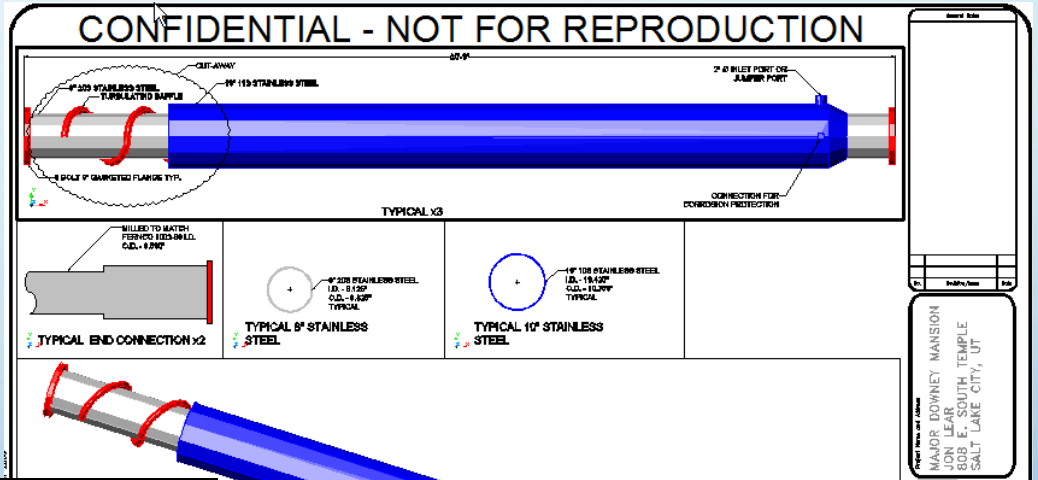
Black/Gray Water Heat Exchange

In-line dual path sewer heat exchanger

Sound Geothermal Corporation



Major George Downey Mansion

208 East South Temple, Salt Lake City

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Low Temperature Geothermal Loop Waste Energy Recovery (WER)

Now let's introduce a way to start to quantify the magnitude of the contribution of WER.

SYSTEM Coefficient of Performance (COP) is the most valid way to compare competing systems.

Consider two systems operating at their respective peaks.

Water Loop – The Thermal Highway©

Goal: Optimize energy savings and minimize water use.
Strategy #1: Recover wasted energy with a distributed energy loop.

Strategy #2: Reduce cooling tower water and reduce electric load.

Strategy #3: Shift load, store energy in the borefield and shed energy at night with the tower.

Energy is ***harvested***, ***moved***, and ***reused****!*
Most wasted energy is recovered.

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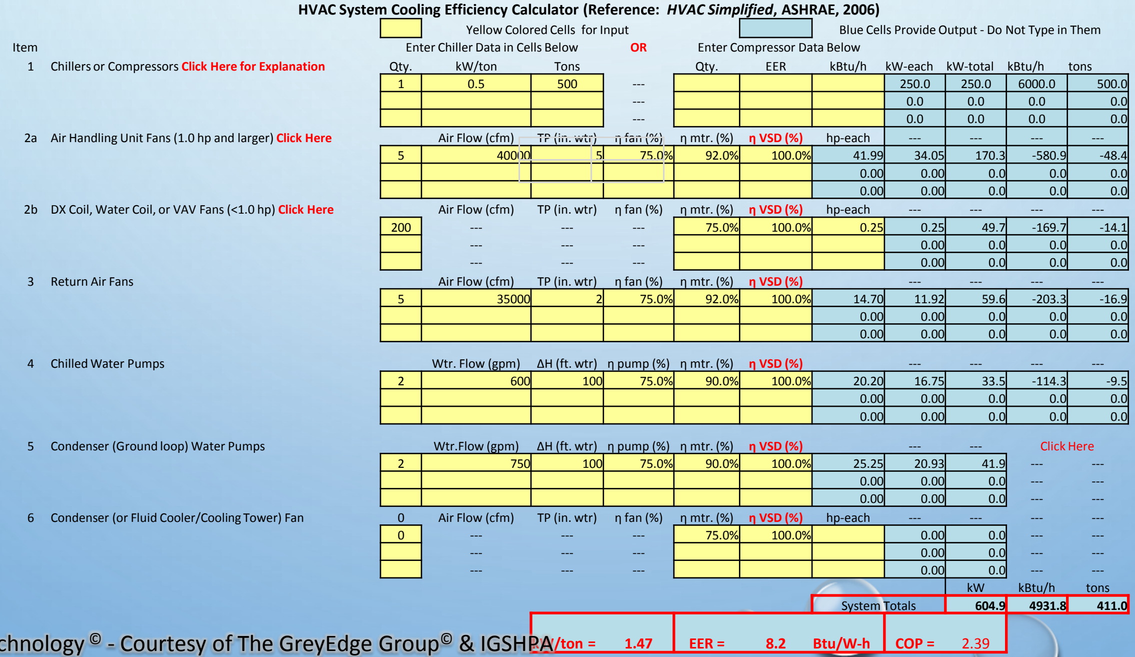
Calculate system COP

System COP uses the energy cost of all of the system components working together, NOT just the "best box" approach.



HVAC System Cooling Efficiency Calculator (Reference: *HVAC Simplified*, ASHRAE, 2006)

🟨 Yellow Colored Cells for Input

🟦 Blue Cells Provide Output - Do Not Type in Them

Item		Enter Chiller Data in Cells Below			**OR**	Enter Compressor Data Below						
1	Chillers or Compressors **Click Here for Explanation**	Qty.	kW/ton	Tons		Qty.	EER	kBtu/h	kW-each	kW-total	kBtu/h	tons
		1	0.5	500	---				250.0	250.0	6000.0	500.0
					---				0.0	0.0	0.0	0.0
					---				0.0	0.0	0.0	0.0
2a	Air Handling Unit Fans (1.0 hp and larger) **Click Here**		Air Flow (cfm)	TP (in. wtr)	η fan (%)	η mtr. (%)	**η VSD (%)**	hp-each	---	---	---	---
		5	40000	5	75.0%	92.0%	100.0%	41.99	34.05	170.3	-580.9	-48.4
								0.00	0.00	0.0	0.0	0.0
								0.00	0.00	0.0	0.0	0.0
2b	DX Coil, Water Coil, or VAV Fans (<1.0 hp) **Click Here**		Air Flow (cfm)	TP (in. wtr)	η fan (%)	η mtr. (%)	**η VSD (%)**	hp-each	---	---	---	---
		200	---	---	---	75.0%	100.0%	0.25	0.25	49.7	-169.7	-14.1
			---	---	---				0.00	0.0	0.0	0.0
			---	---	---				0.00	0.0	0.0	0.0
3	Return Air Fans		Air Flow (cfm)	TP (in. wtr)	η fan (%)	η mtr. (%)	**η VSD (%)**		---	---	---	---
		5	35000	2	75.0%	92.0%	100.0%	14.70	11.92	59.6	-203.3	-16.9
								0.00	0.00	0.0	0.0	0.0
								0.00	0.00	0.0	0.0	0.0
4	Chilled Water Pumps		Wtr. Flow (gpm)	ΔH (ft. wtr)	η pump (%)	η mtr. (%)	**η VSD (%)**		---	---	---	---
		2	600	100	75.0%	90.0%	100.0%	20.20	16.75	33.5	-114.3	-9.5
								0.00	0.00	0.0	0.0	0.0
								0.00	0.00	0.0	0.0	0.0
5	Condenser (Ground loop) Water Pumps		Wtr.Flow (gpm)	ΔH (ft. wtr)	η pump (%)	η mtr. (%)	**η VSD (%)**		---	---	Click Here	
		2	750	100	75.0%	90.0%	100.0%	25.25	20.93	41.9	---	---
								0.00	0.00	0.0	---	---
								0.00	0.00	0.0	---	---
6	Condenser (or Fluid Cooler/Cooling Tower) Fan	0	Air Flow (cfm)	TP (in. wtr)	η fan (%)	η mtr. (%)	**η VSD (%)**	hp-each	---	---	---	---
		0	---	---	---	75.0%	100.0%		0.00	0.0	---	---
			---	---	---				0.00	0.0	---	---
			---	---	---				0.00	0.0	---	---
										kW	kBtu/h	tons
								System Totals		**604.9**	**4931.8**	**411.0**

kW/ton = 1.47 **EER = 8.2 Btu/W-h** **COP = 2.39**

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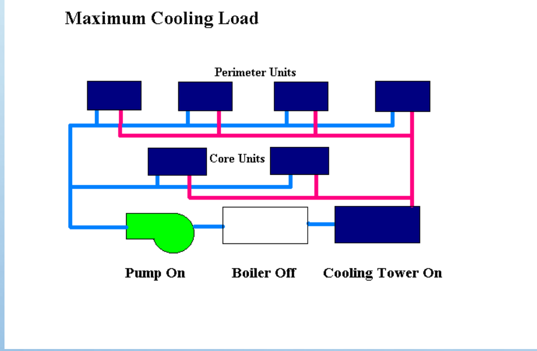
FOR EXAMPLE:
SYSTEM EFFICIENCYTwo

Independent Buildings **500** tons each

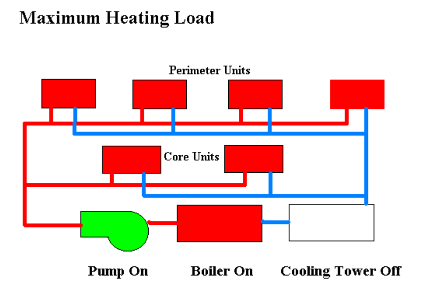
ICE PLANT

Chiller/Tower



LAUNDRY/FOOD SERVICE

Hot Water Load - Boiler



SYSTEM kW/ton = 3.0 EER = 4.0 Btu/W-h

COP = 1.17

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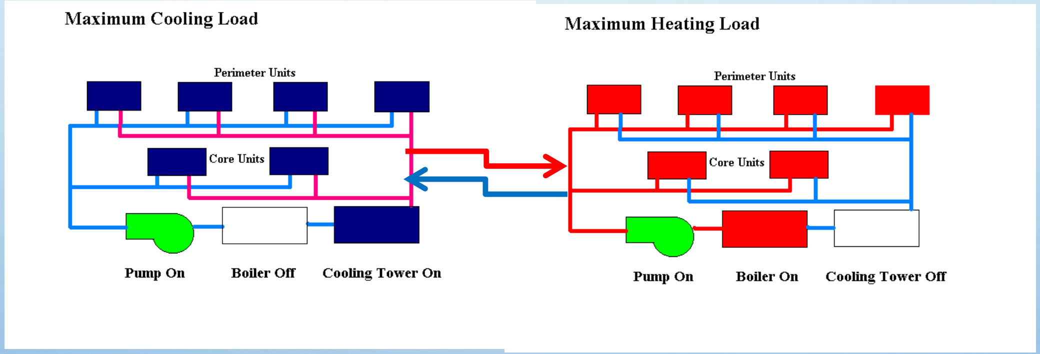
SYSTEM EFFICIENCY
District Energy System - Two Buildings
500 tons each

Coincidental *Connected* Loads

ICE PLANT
HEAT PUMPS

LAUNDRY/FOOD SERVICE
HEAT PUMPS



kW/ton = 0.71 **EER = 16.9 Btu/W-h** **COP = 4.96**

Shed 100 kW and 7.14MM BTU/h NG
7.14 decatherms/h = 2,093 kWh

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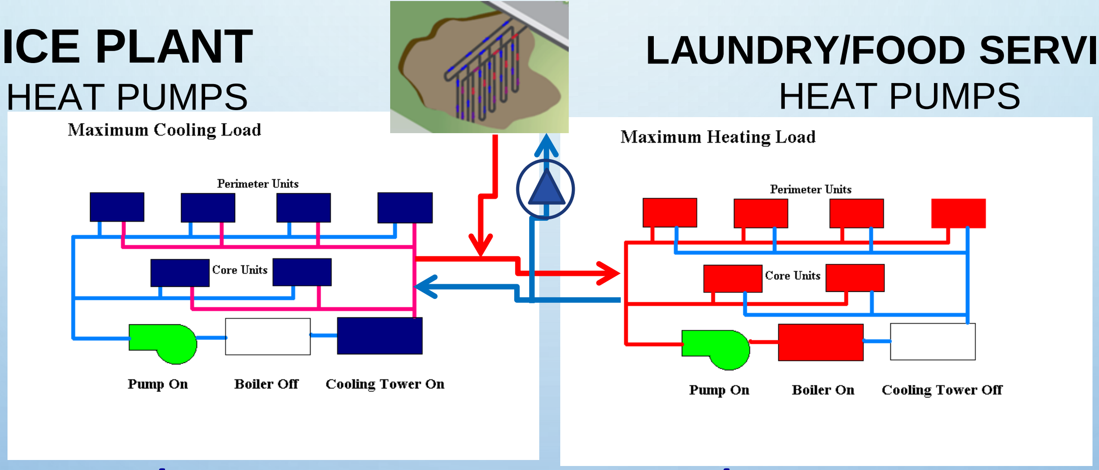
SYSTEM EFFICIENCY
District Energy System - Two Buildings
500 Tons Each

__Non-Coincidental Connected__ Loads

Add Ground Heat Exchanger / Thermal Storage

ICE PLANT
HEAT PUMPS

LAUNDRY/FOOD SERVICE
HEAT PUMPS



kW/ton = 0.75 EER = 16.0 Btu/W-h COP = 4.68

Reduces peak savings slightly but increases WER hours per year.

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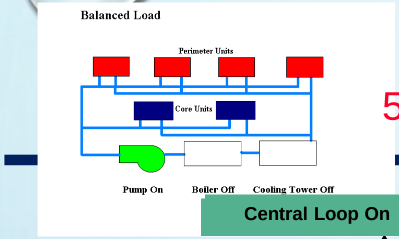
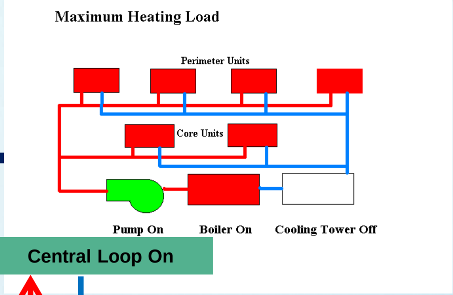


Central Loop On

55F to 85F

Stage 1 – building moves energy internally using building pumps.

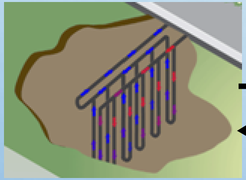


Central Loop On

Central Loop 50F to 85F

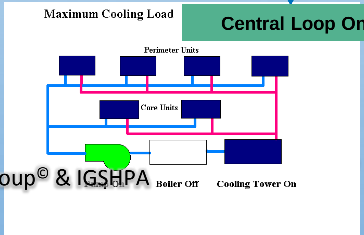
Stage 2 – building(s) move energy to or from the central loop.

Least Energy Path™



Stage 3 – Central Loop calls Borefield (hot or cold).

<50F or >85F



Central Loop On

Stage 4 – Central Loop calls Boiler or Fluid Cooler (hot or cold).

<40F or >90F

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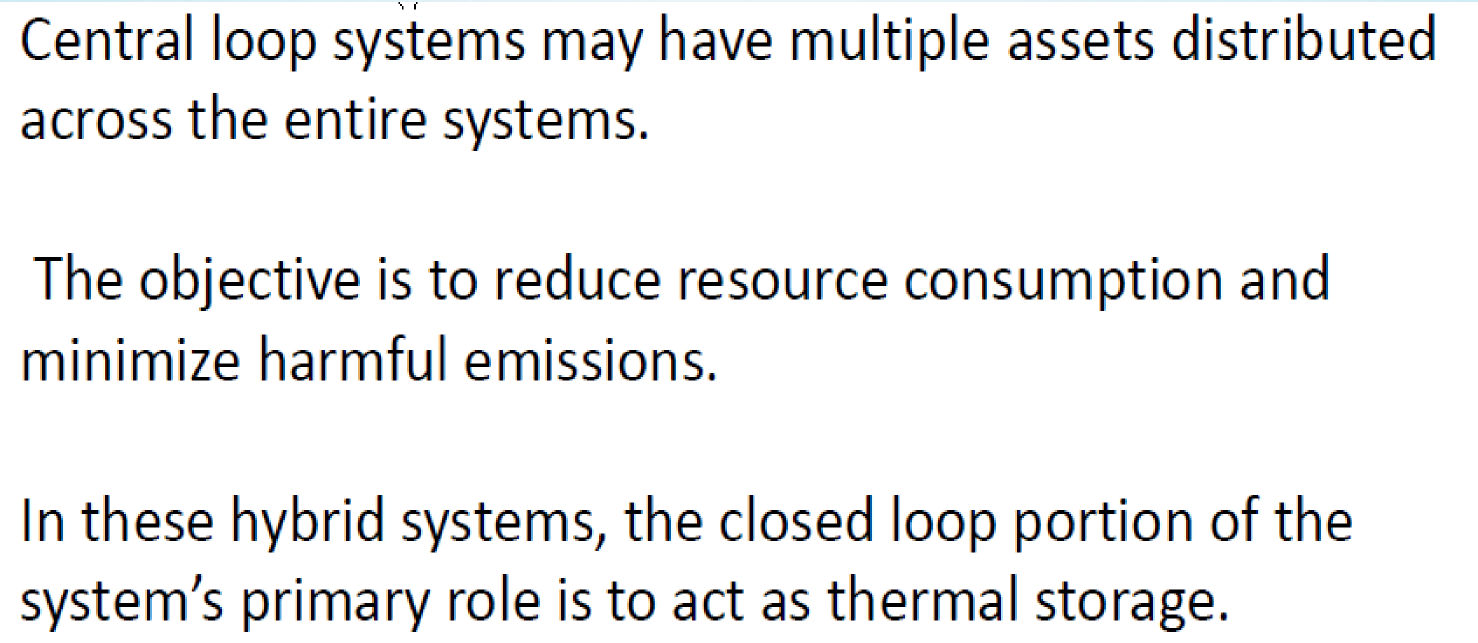
Thermal Highway© Systems



Central loop systems may have multiple assets distributed across the entire systems.

The objective is to reduce resource consumption and minimize harmful emissions.

In these hybrid systems, the closed loop portion of the system’s primary role is to act as thermal storage.

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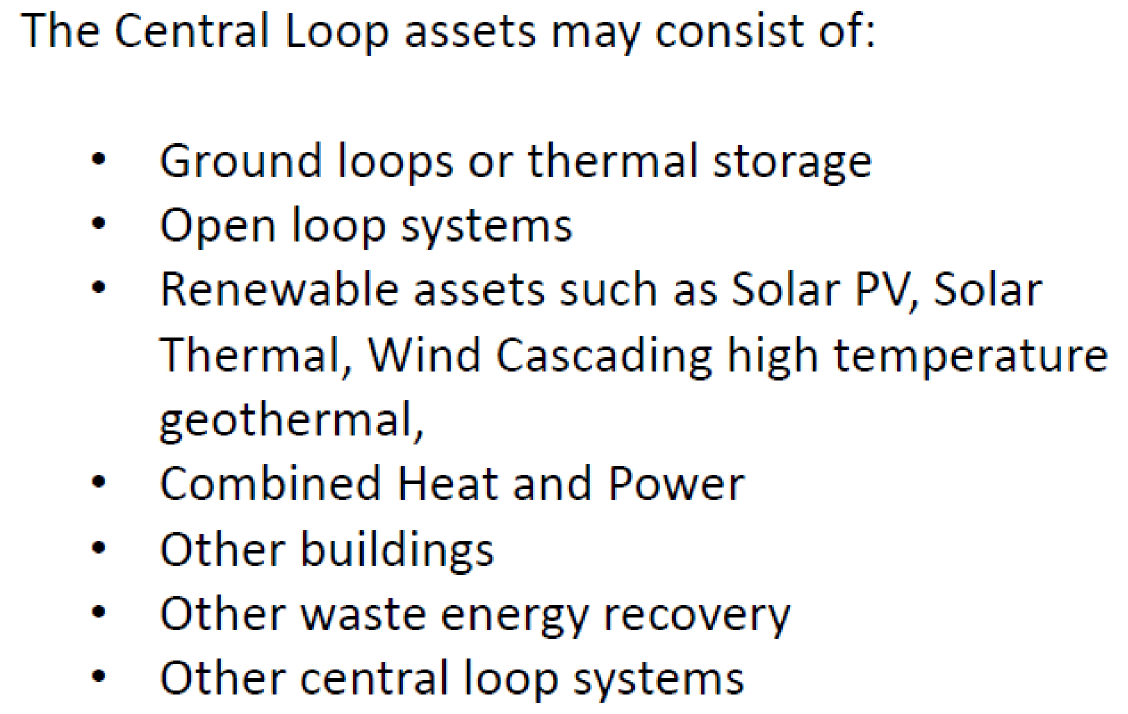
The Thermal Highway© Systems



The Central Loop assets may consist of:

- Ground loops or thermal storage
- Open loop systems
- Renewable assets such as Solar PV, Solar Thermal, Wind Cascading high temperature geothermal,
- Combined Heat and Power
- Other buildings
- Other waste energy recovery
- Other central loop systems

Heat Pump Technology Advancements

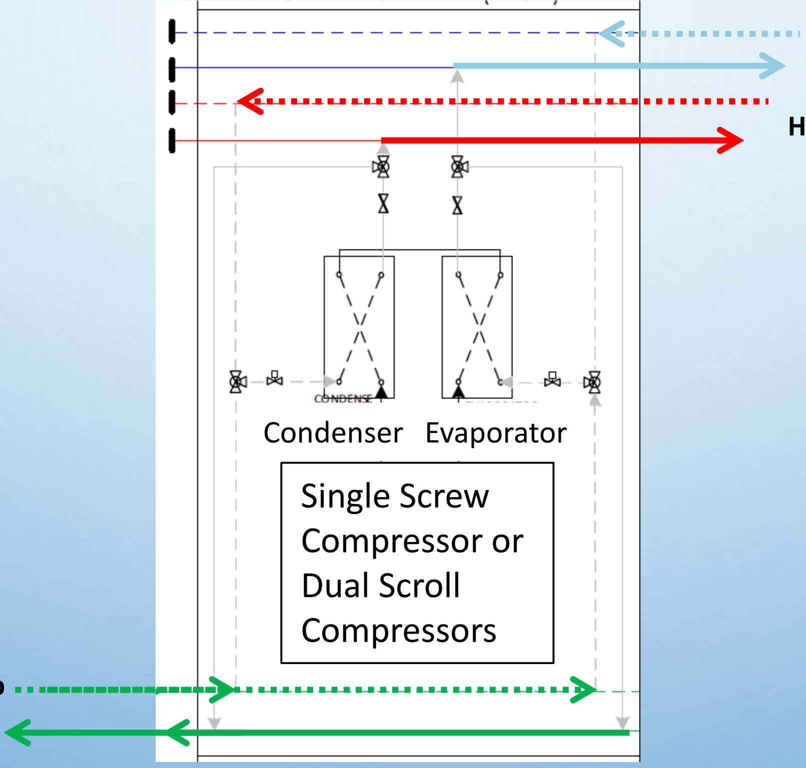
Six Pipe Simultaneous Chiller/Boiler

Ideal for retrofit of an existing system where we will be using a modified chilled water, stepped, conversion.

How It Works:

- Parallel piped distribution vs one-pipe
- Temporarily, all of the buildings are plumbed to both CWS and CWR and “best” temperature fluid is used.
- Driver buildings during chilled water delivery.
- All buildings when the chillers and boiler are “OFF”
- Hot load water is NOT delivered in favor of ambient or stored fluid temperatures

Six Pipe Simultaneous Chiller/Boiler



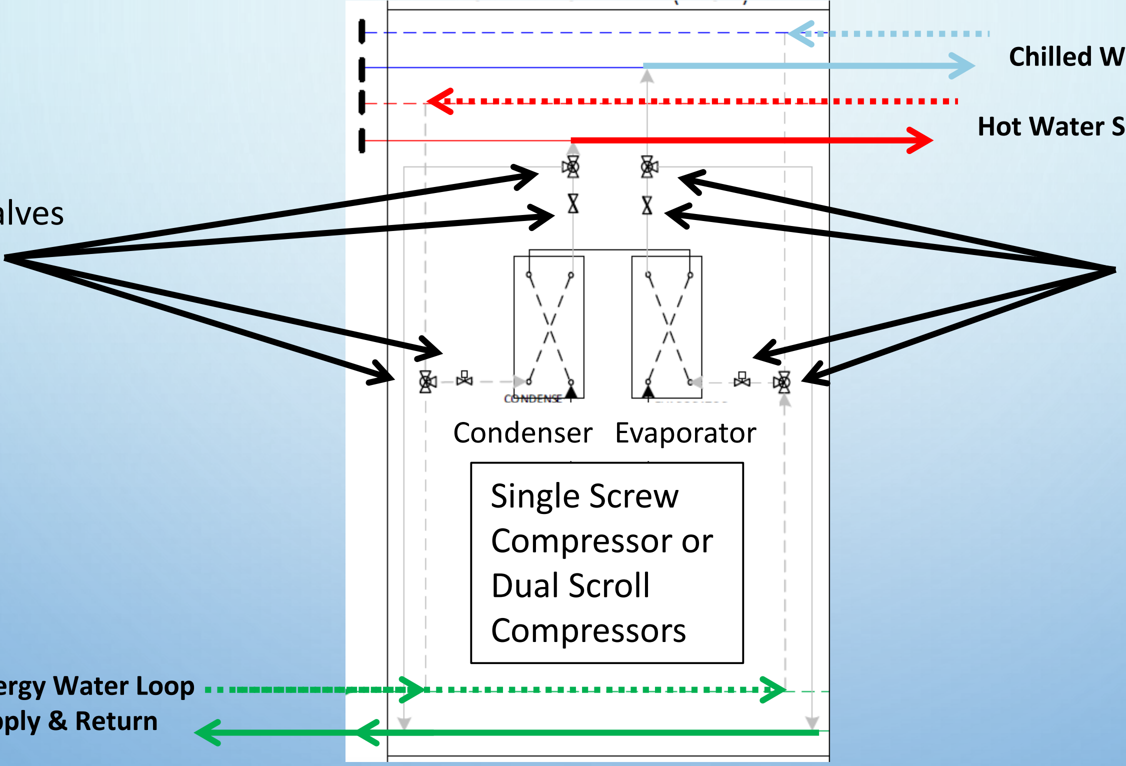
Chilled Water Supply & Return

Hot Water Supply & Return

Single Screw Compressor or Dual Scroll Compressors

Net Energy Water Loop Supply & Return

Six Pipe Simultaneous Chiller/Boiler



Chilled Water Supply & Return

Hot Water Supply & Return

Two Way Water Valves
And
Three Way Valves

Two Way Water Valves
And
Three Way Valves

Condenser

Evaporator

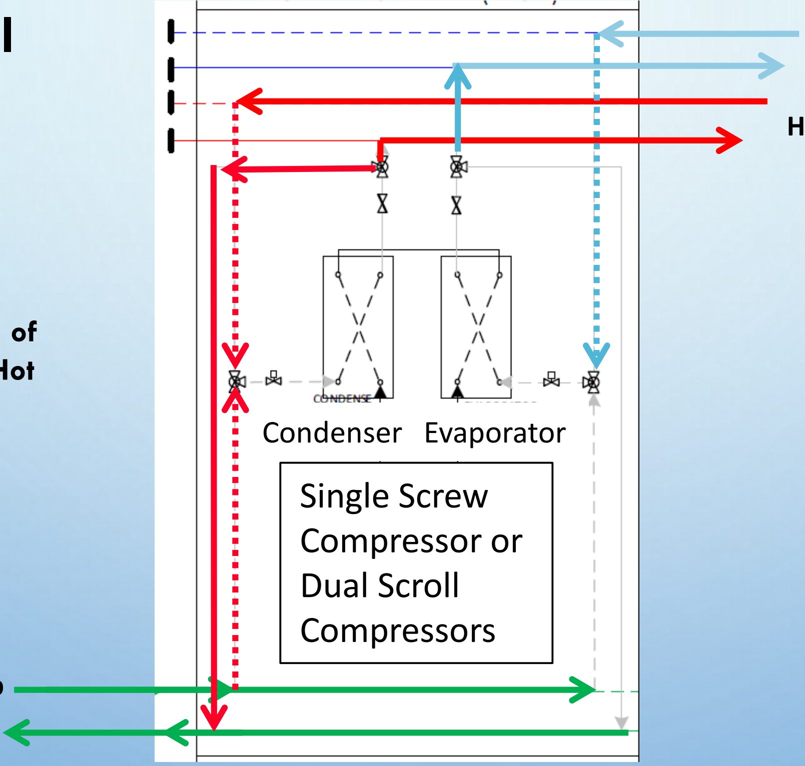
Single Screw
Compressor or
Dual Scroll
Compressors

Net Energy Water Loop
Supply & Return

Six Pipe Simultaneous Chiller/Boiler

Imbalanced or Partial Simultaneous Mode

Allows for simultaneous control of both the Chilled Water and the Hot Water Set Point



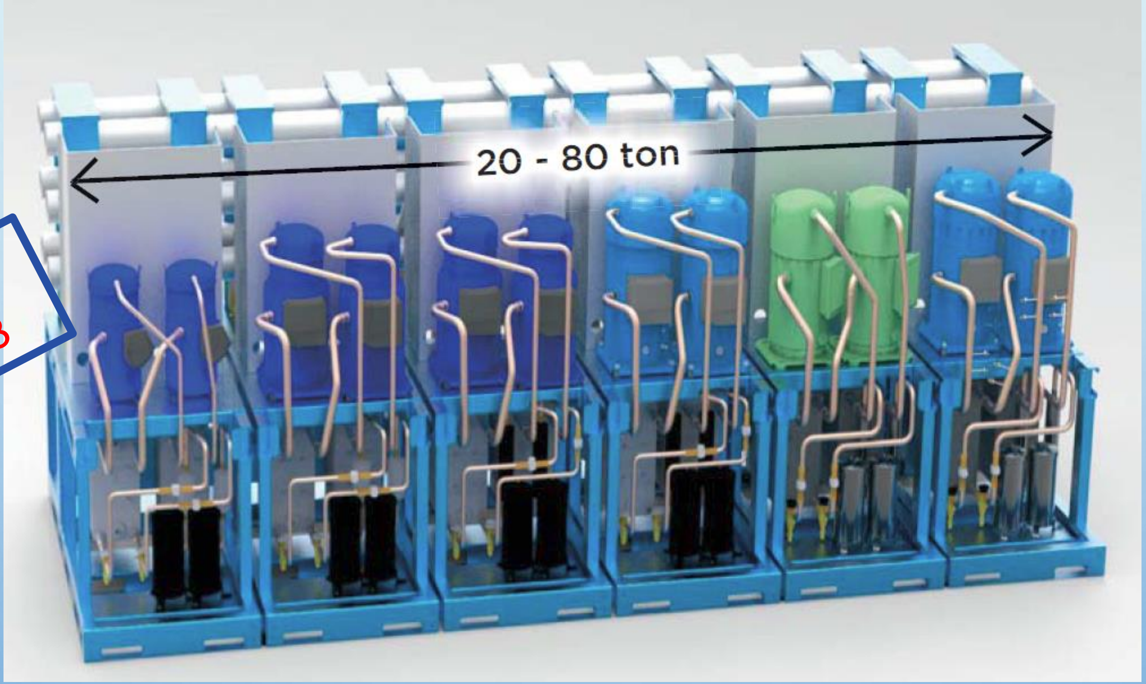
Chilled Water Supply & Return

Hot Water Supply & Return

Net Energy Water Loop Supply & Return

Modular Chillers

Removable Main Header Rack



Peak COP - 8
Peak EER - 28

C Series Packaged Chillers – 134a

Enclosed Chiller: Single & Dual Screw 30 – 300 Tons

Output to 165 F

GreyEdge Group
801-942-6100

gewbank@greyedgegroup.com

gsexton@greyedgegroup.com

csmith@greyedgegroup.com

Questions?

IGSHPA

Comfort from the ground up

Powered by R-718 Technology © - Courtesy of The GreyEdge Group© & IGSHPA

C Series Packaged Chillers

Screw Compressor

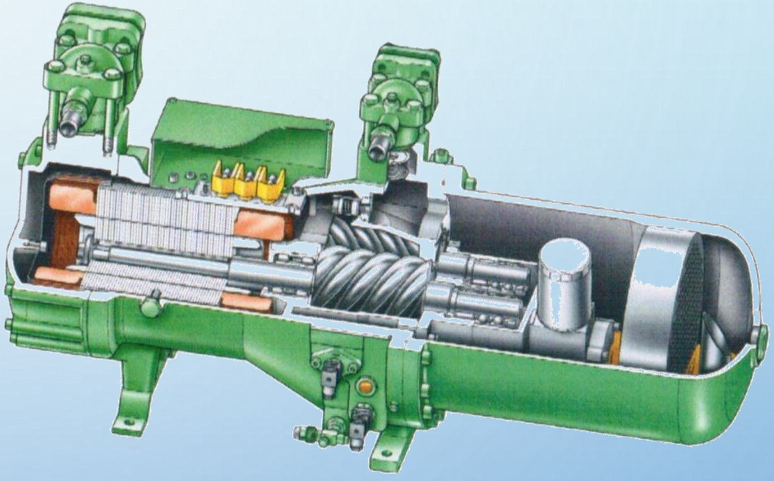
R134A

Variable Capacity 25-100%

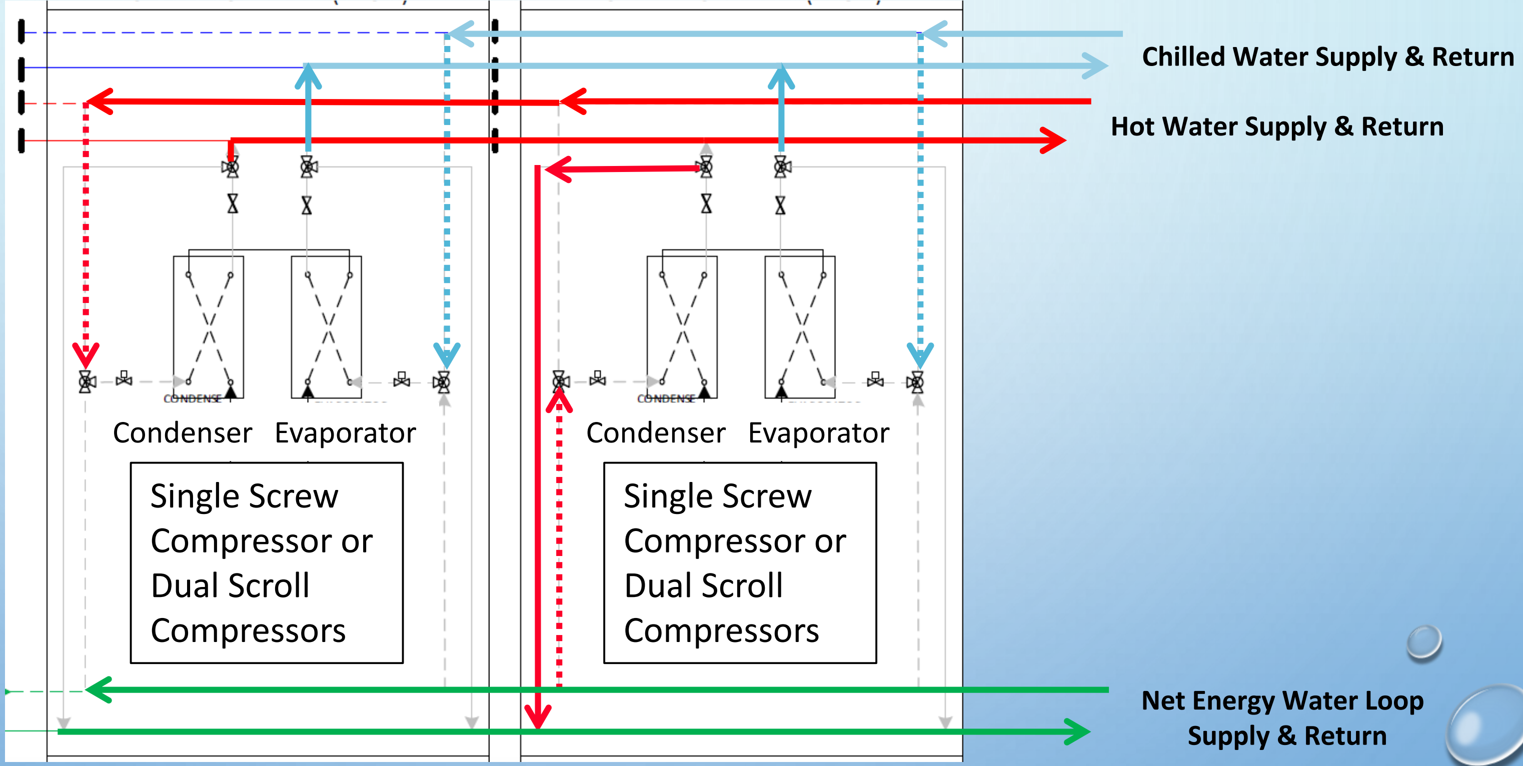
Easily capable of 140F LWT

Longevity and Durability

Low maintenance, lesser start/stops

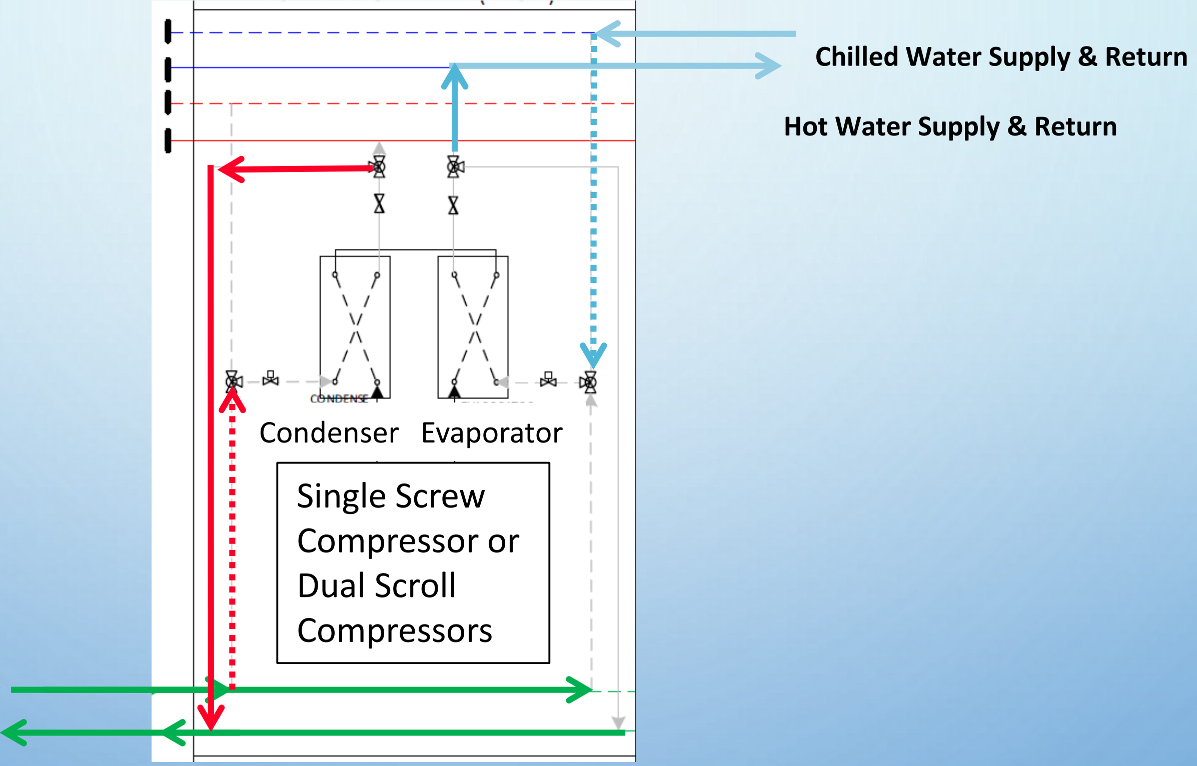


Six Pipe Simultaneous Chiller/Boiler


Chilled Water Supply & Return
Hot Water Supply & Return
CONDENSE
CONDENSE
Condenser
Evaporator
Condenser
Evaporator
Single Screw Compressor or Dual Scroll Compressors
Single Screw Compressor or Dual Scroll Compressors
Net Energy Water Loop Supply & Return

Six Pipe Simultaneous Chiller/Boiler

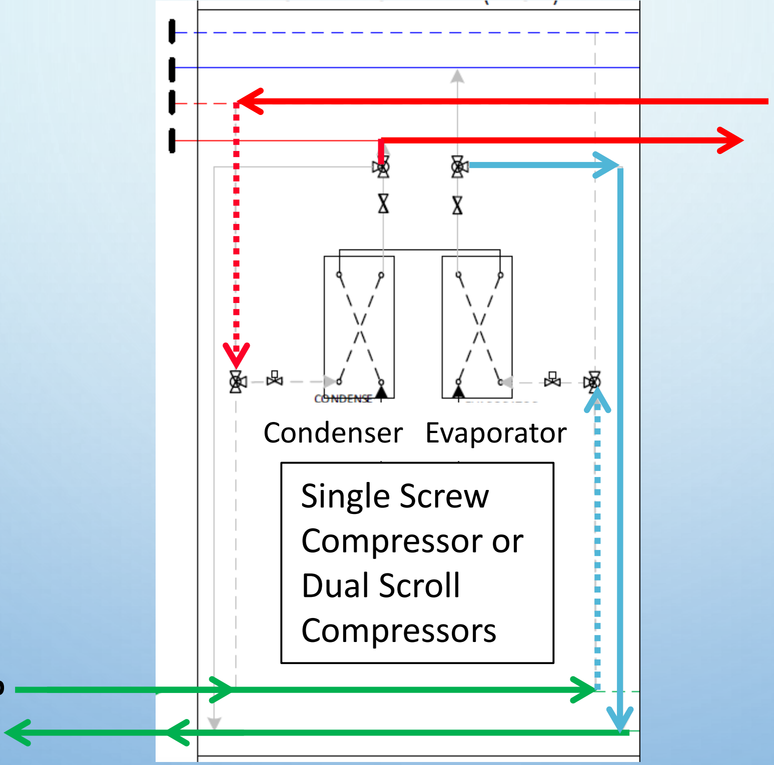
Chilled Water Mode


Chilled Water Supply & Return
Hot Water Supply & Return
CONDENSE
Condenser
Evaporator
Net Energy Water Loop Supply & Return

Single Screw Compressor or Dual Scroll Compressors

Six Pipe Simultaneous Chiller/Boiler

Hot Water Mode



Chilled Water Supply & Return

Hot Water Supply & Return

Condenser

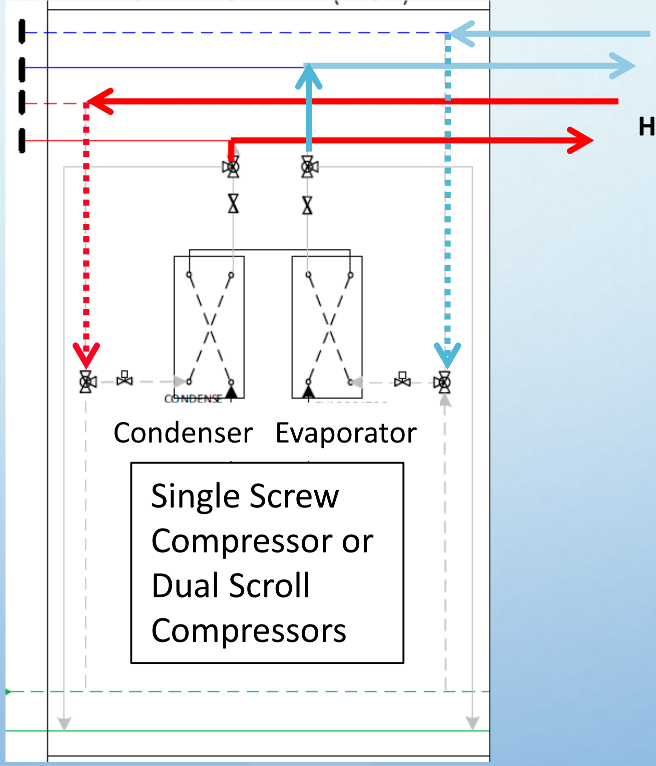
Evaporator

Single Screw Compressor or Dual Scroll Compressors

Net Energy Water Loop Supply & Return

Six Pipe Simultaneous Chiller/Boiler

Balanced Simultaneous Chilled Water & Hot Water Mode



Single Screw Compressor or Dual Scroll Compressors

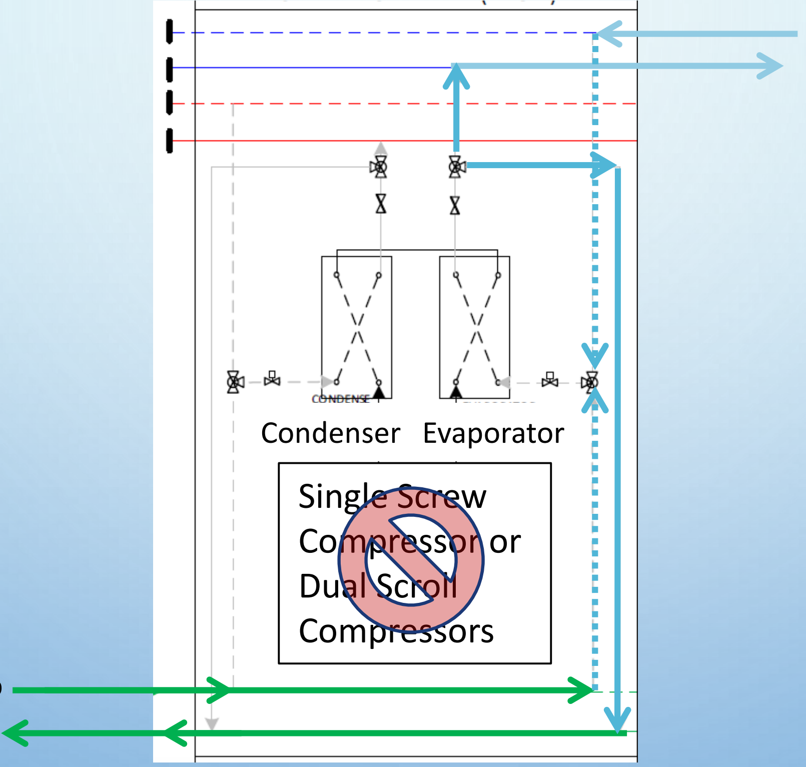
Chilled Water Supply & Return

Hot Water Supply & Return

Net Energy Water Loop Supply & Return

Six Pipe Simultaneous Chiller/Boiler

Waterside Economizer Mode

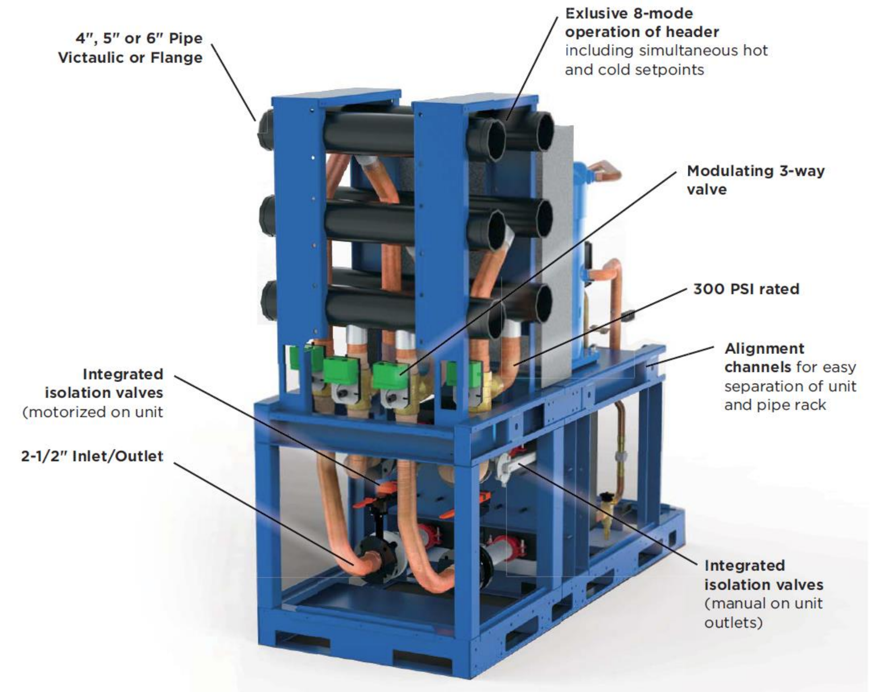


Chilled Water Supply & Return

Net Energy Water Loop Supply & Return

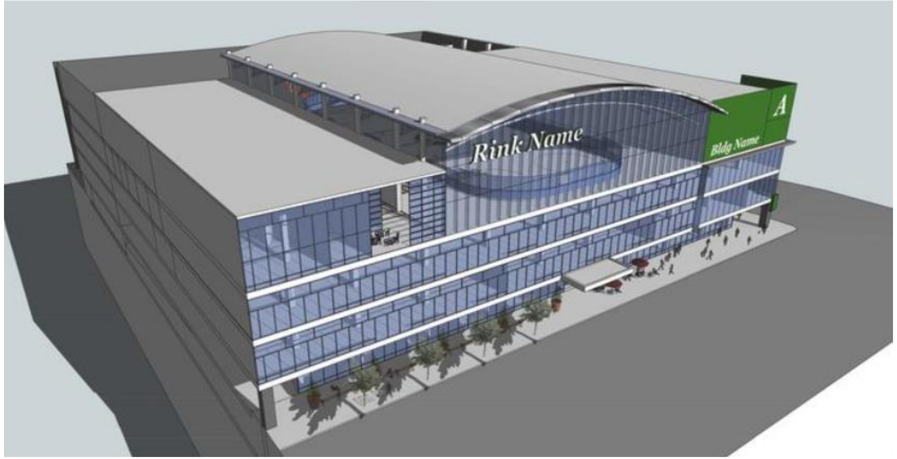
Modular Chillers – 410a

Modular Dual Scroll 20 – 80 Ton



Sharing Energy

Energy Flow



Needed Energy

- Heat = 0
- Cold = 300

____

____

Hockey Rink

Rejected Energy

- Heat = 300 + ________________________ ____
- Cold = 0

Energy Flow

Needed Energy

- Heat = 50
- Cold = 20

____

____

_____

Hotel

Rejected Energy

- Heat = 20 +
- Cold = 40 + __________

Energy Flow

Needed Energy
- Heat = 0
- Cold = 300

____

____

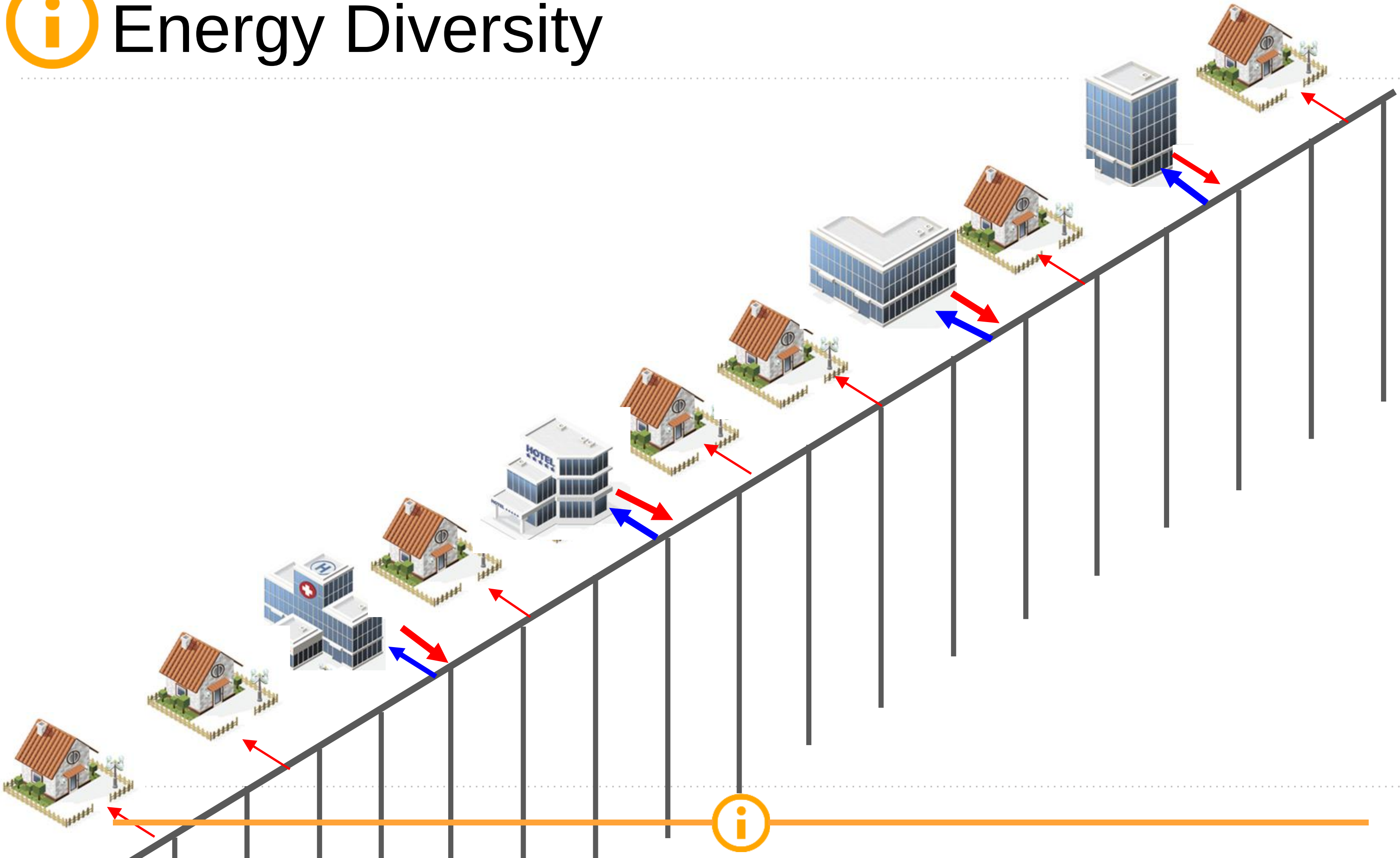
Data Center

Rejected Energy
- Heat = 300 +
- Cold = 0

____

____

Energy Diversity



The GeoMicroDistrict
Approach for a Utility-Scale
Transition to Clean Energy...

2019-10-28

Optimizing GSHP Systems for District Energy

Ed Lohrenz, BES, CGD

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ed@geoptimize.ca

GEOptimize.ca

Beneficial electrification and ground source heat pumps

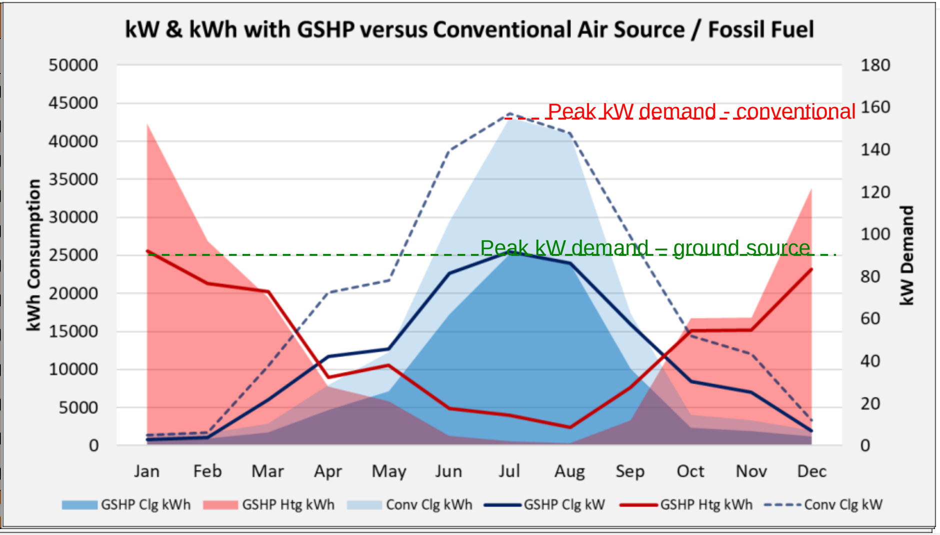
A typical building with a GSHP system has a lower peak electrical demand and requires more electricity per year.

- Peak demand reduced 41%
- kWh consumption increased 39%

	Ground Source System				Conv Cooling & Fossil Fuel Heating			
	Clg kWh	Clg kW	Htg kWh	Htg kWh	Clg kWh	Clg kW	Htg kWh	Htg kW
Jan	937	3	42304	92	1605	5	0	0
Feb	968	4	26815	77	1660	6	0	0
Mar	1704	22	19513	73	2921	38	0	0
Apr	4644	42	7784	32	7962	72	0	0
May	7182	46	3804	38	12312	78	0	0
Jun	17132	81	1298	17	29368	140	0	0
Jul	25155	92	606	14	43123	157	0	0
Aug	23911	86	294	9	40991	148	0	0
Sep	10108	58	3314	27	17328	99	0	0
Oct	2332	30	16744	54	3998	52	0	0
Nov	1927	25	16854	55	3303	43	0	0
Dec	1161	7	33822	83	1989	12	0	0
	97,160	92	175,152	92	166,561	157	0	0

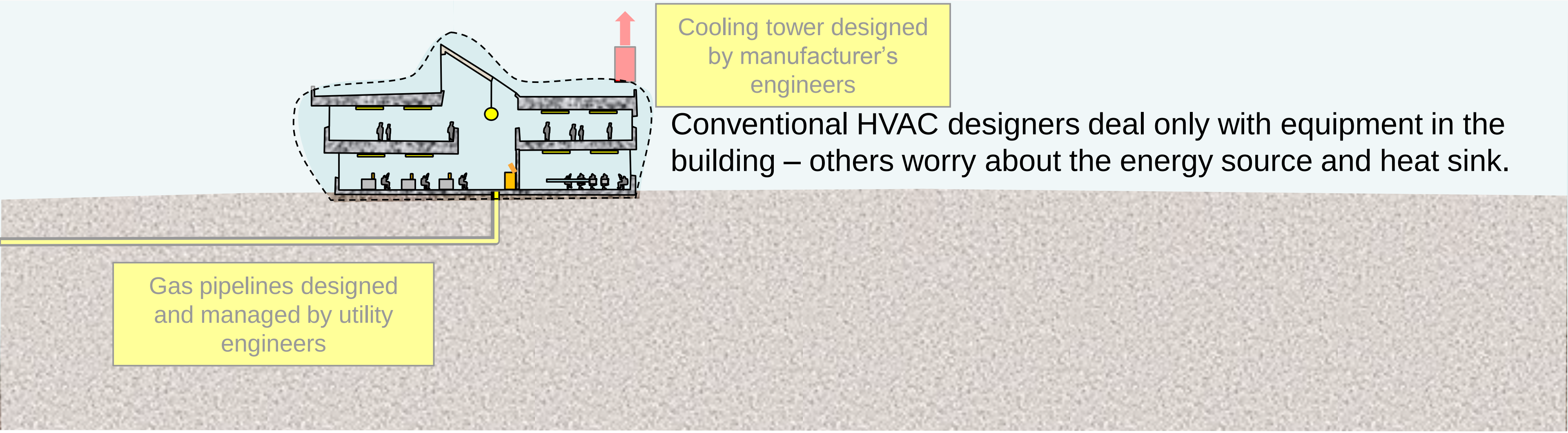
92 kW
97,160 + 175,152 =
272,312 kWh

157 kW
166,561 kWh



Conventional HVAC system design

The energy source for most conventional HVAC systems is designed and operated by engineers external to the building. The heat sink (cooling tower) is designed by outside engineers working for a manufacturer and selected from a website by the mechanical system designer.



Cooling tower designed by manufacturer's engineers

Conventional HVAC designers deal only with equipment in the building – others worry about the energy source and heat sink.

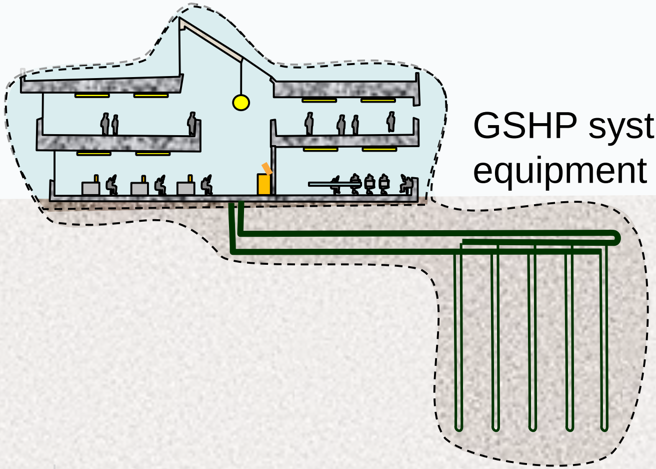
Gas pipelines designed and managed by utility engineers

External energy sources require extensive engineering

Conventional building systems connected to infinite energy source designed and managed by engineers with the utility. Mechanical system designer only connects to the utility pipes…doesn’t design the energy source.

GSHP system design

Just like a conventional HVAC system designer, the inside equipment and distribution system is designed by the GSHP system designer…but they also have to design the energy source / heat sink for the system.



GSHP system designers deal with equipment inside the building,

But they also have to design the energy source / heat sink

Rules of thumb

“Rules of thumb” are designed to provide quick answers. The answers may be adequate for sizing a conventional HVAC system…but when responding to a client about the feasibility of a GSHP system they don’t address the many variables that affect the size and cost of the energy source…the GHX.

Rules of thumb applied to three projects

Based on typical rules of thumb a church, retail store and apartment building with the same peak heating load (32 tons) and peak cooling load (40 tons) would need a vertical GHX of 40 tons x 200’ per ton = 8,000’ of borehole.

Cooling: 480 kBtu/hr
Heating: 385 kBtu/hr

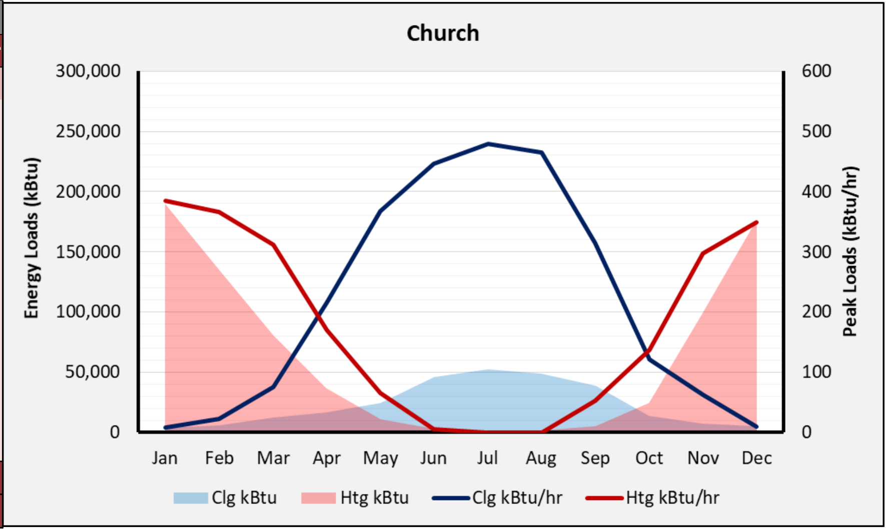
Cooling: 480 kBtu/hr
Heating: 385 kBtu/hr

Cooling: 480 kBtu/hr
Heating: 385 kBtu/hr

Church loads driven by Sunday morning services

A church is only occupied a few hours a week…that’s what drives the peak cooling load. Outdoor temperatures drive the heating load the rest of the week.

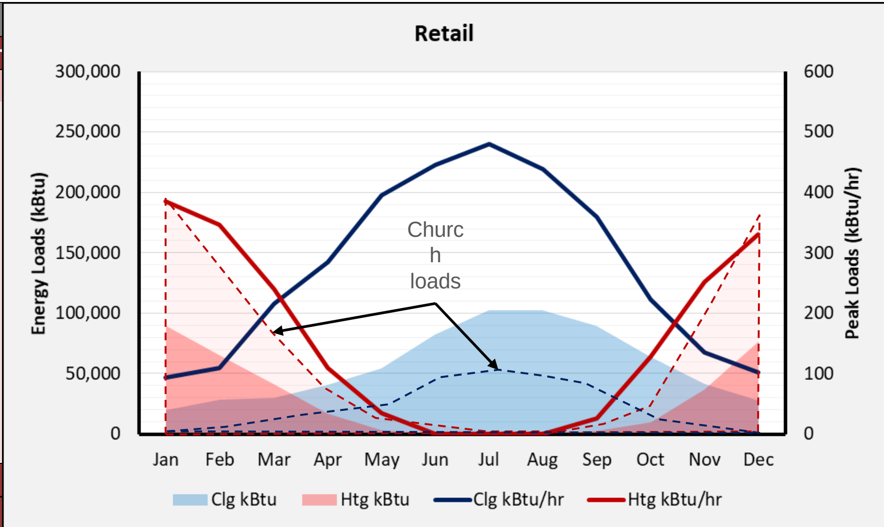
A	Church			
	Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr
Jan	3820	8	189734	**385**
Feb	6202	23	135120	366
Mar	12177	76	81304	312
Apr	16800	216	36614	170
May	24640	367	11152	65
Jun	46285	446	3180	5
Jul	52680	**480**	886	0
Aug	49068	465	1725	0
Sep	38560	314	5479	53
Oct	13821	121	24702	137
Nov	7571	62	98784	298
Dec	4884	10	176775	348
	276508	**480**	**765455**	**385**
	EFLH	576	EFLH	1986



Retail store loads driven by occupancy and lighting

Peak heating and cooling loads in retail are identical to the church, but annual cooling loads (Clg kBtu) are 250% higher and annual heating loads (Htg kBtu) are 55% lower than the church.

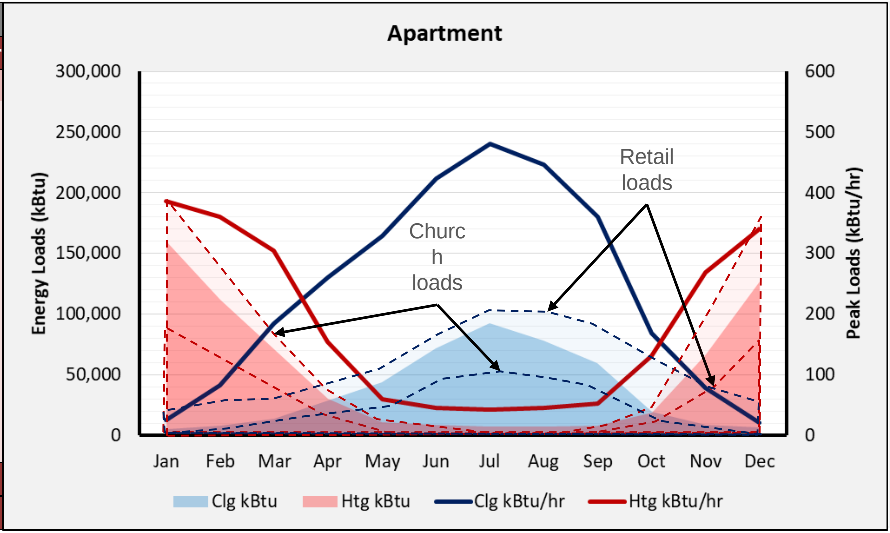
B	Retail			
	Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr
Jan	19906	93	89734	**385**
Feb	28202	110	65120	346
Mar	30177	215	41304	240
Apr	40866	285	16614	110
May	53946	396	3152	35
Jun	82094	446	180	0
Jul	102358	**480**	0	0
Aug	102393	439	125	0
Sep	89245	360	2379	26
Oct	63821	223	9702	128
Nov	41571	135	36784	251
Dec	27884	102	76775	331
	682463	**480**	**341869**	**385**
	EFLH	1422	EFLH	887



Apartment building loads driven by occupancy

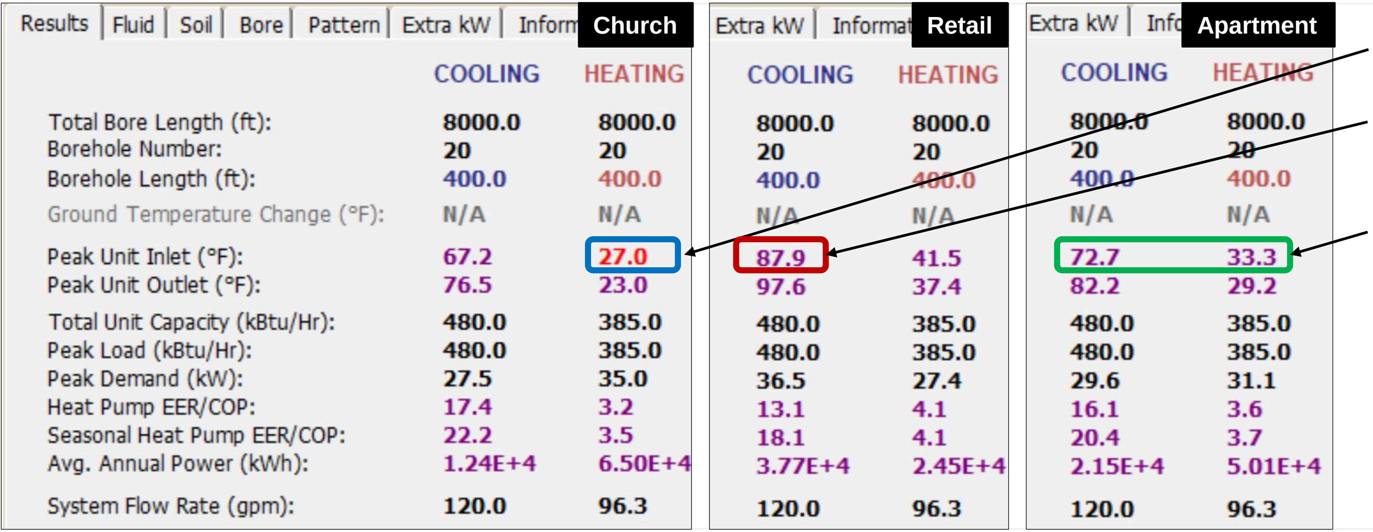
Peak loads in the apartment building are identical to the church and retail store, but annual heating and cooling loads are more balanced, especially when compressor energy is considered.

C	Apartment			
	Clg kBtu	Clg kBtu/hr	Htg kBtu	Htg kBtu/hr
Jan	5560	25	159734	**385**
Feb	7840	83	112120	360
Mar	14177	185	71304	305
Apr	28866	260	30614	155
May	43946	329	11152	60
Jun	72094	423	8545	45
Jul	92358	**480**	7650	43
Aug	78393	447	7550	45
Sep	59450	360	8479	53
Oct	19821	169	18702	132
Nov	8690	79	66784	269
Dec	6570	22	126775	340
	437765	480	629409	385
	EFLH	912	EFLH	1633



Performance of "rule of thumb" GHX design

Modeling the size of GHX for each building based on the "200' of borehole / ton" rule of thumb results in different performance for each GHX. The temperature of the GHX for the church drops to 27°F while the retail building increases to 87.9°F.



	Church COOLING	Church HEATING	Retail COOLING	Retail HEATING	Apartment COOLING	Apartment HEATING
Total Bore Length (ft):	8000.0	8000.0	8000.0	8000.0	8000.0	8000.0
Borehole Number:	20	20	20	20	20	20
Borehole Length (ft):	400.0	400.0	400.0	400.0	400.0	400.0
Ground Temperature Change (°F):	N/A	N/A	N/A	N/A	N/A	N/A
Peak Unit Inlet (°F):	67.2	27.0	87.9	41.5	72.7	33.3
Peak Unit Outlet (°F):	76.5	23.0	97.6	37.4	82.2	29.2
Total Unit Capacity (kBtu/Hr):	480.0	385.0	480.0	385.0	480.0	385.0
Peak Load (kBtu/Hr):	480.0	385.0	480.0	385.0	480.0	385.0
Peak Demand (kW):	27.5	35.0	36.5	27.4	29.6	31.1
Heat Pump EER/COP:	17.4	3.2	13.1	4.1	16.1	3.6
Seasonal Heat Pump EER/COP:	22.2	3.5	18.1	4.1	20.4	3.7
Avg. Annual Power (kWh):	1.24E+4	6.50E+4	3.77E+4	2.45E+4	2.15E+4	5.01E+4
System Flow Rate (gpm):	120.0	96.3	120.0	96.3	120.0	96.3

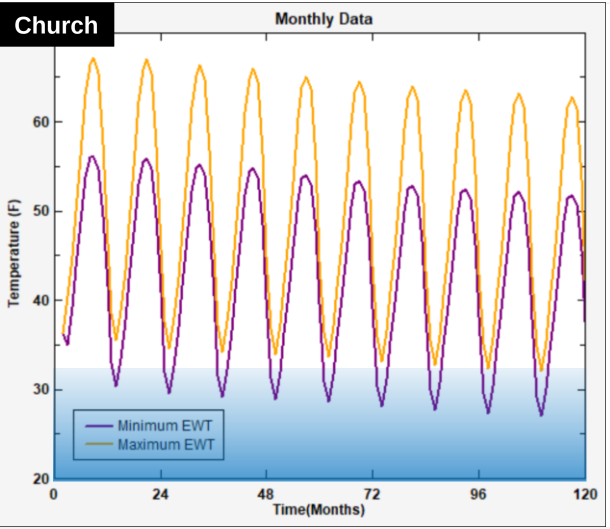
Temperature too low

Temperature too high

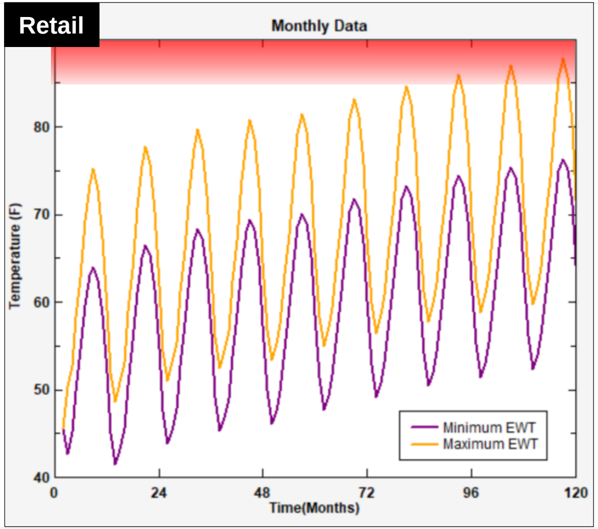
Temperatures just right

Long term performance of GHX’s

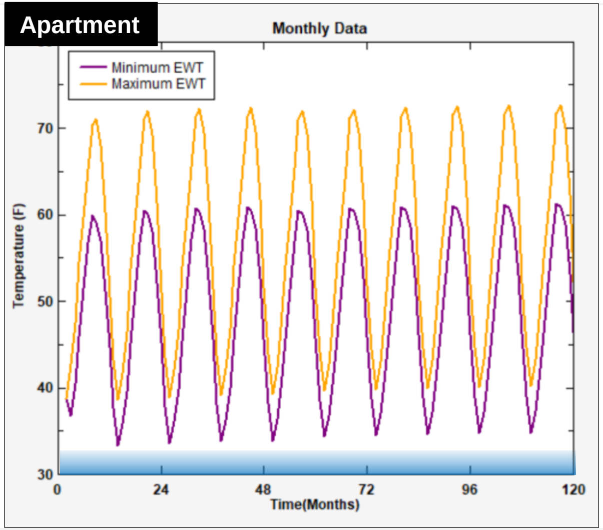
After 10 years the winter time temperature of the GHX for the church drops to 27°F. Temperatures in the retail store increase after 10 years to about 88°F. The GHX in the apartment operates within temperature range throughout.



Church



Retail

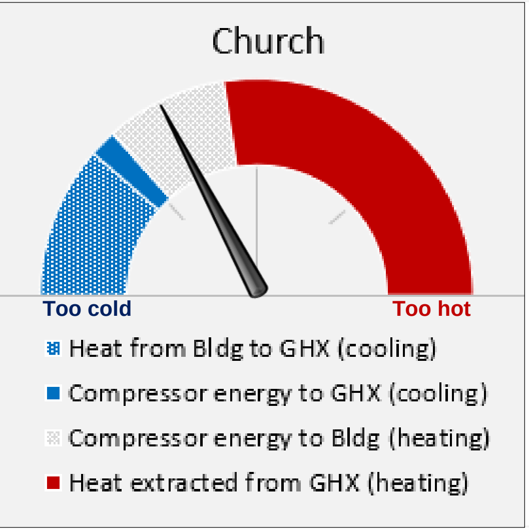


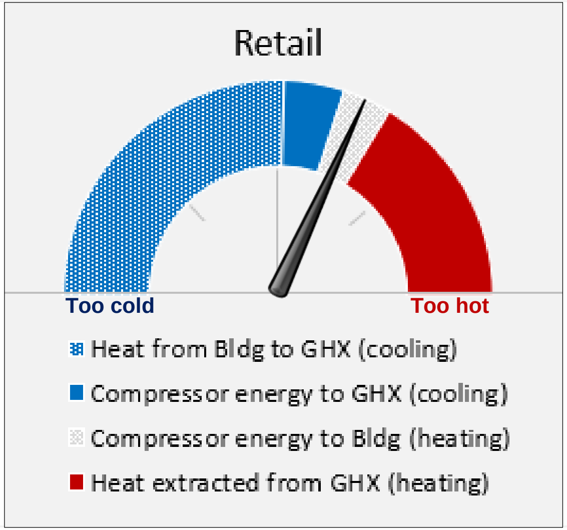
Apartment

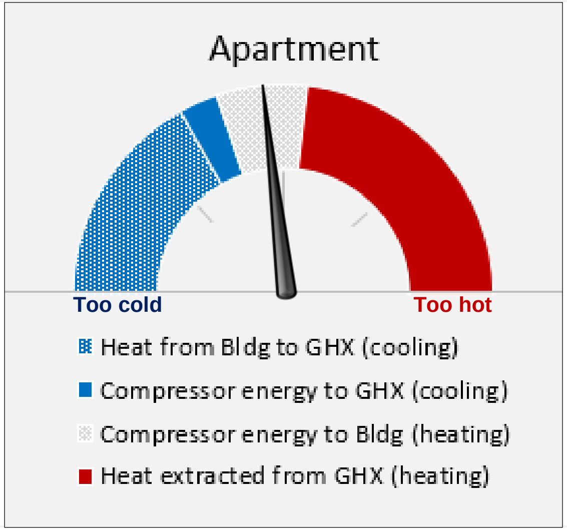
Energy balance

Energy transferred to and from the GHX includes compressor and pump energy.

- Church extracts more energy from the GHX than it rejects…is “heating dominant”
- Retail rejects more energy to the GHX than it extracts…is “cooling dominant”
- Apartment rejects almost as much energy as it extracts…is “balanced”

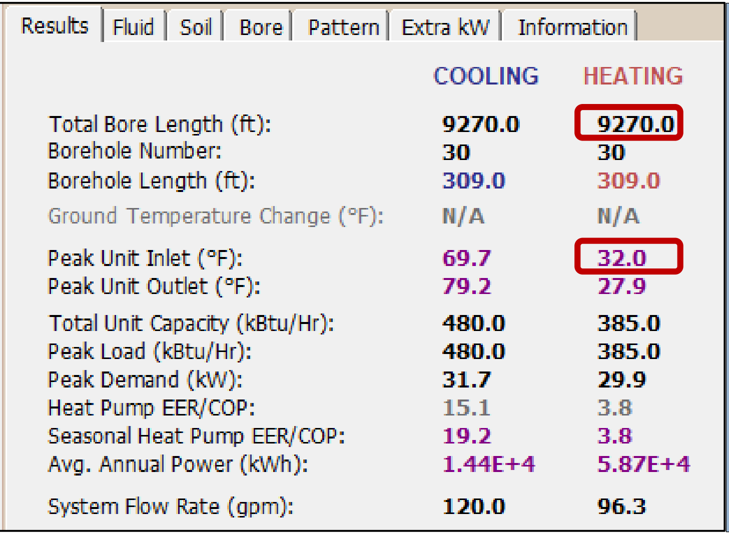




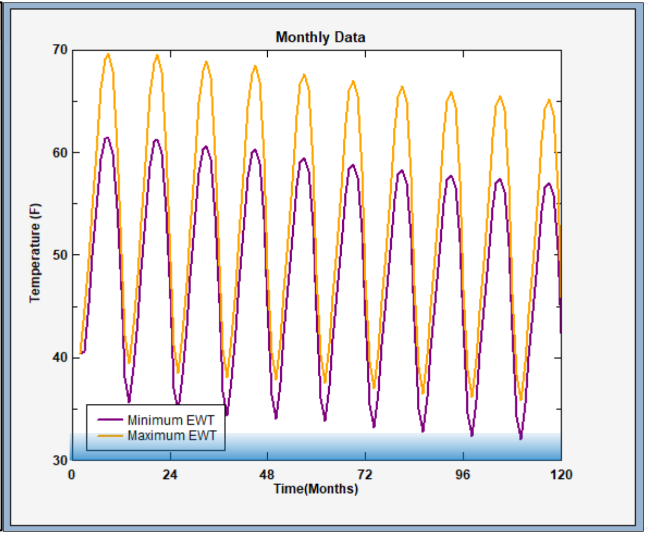


Increasing the size of the GHX for the church

Increasing the size of the GHX from 8,000’ of borehole to 9,270’ (232’ / ton) extends the length of time till the temperature of the GHX drops outside of efficient operating parameters.

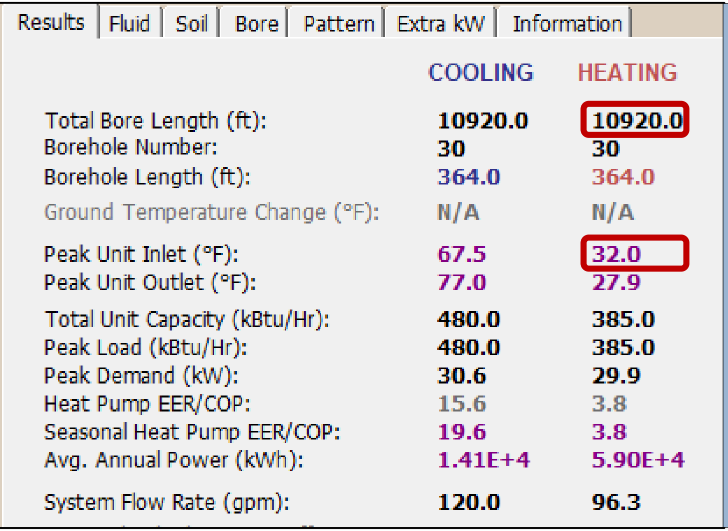


	COOLING	HEATING
Total Bore Length (ft):	9270.0	9270.0
Borehole Number:	30	30
Borehole Length (ft):	309.0	309.0
Ground Temperature Change (°F):	N/A	N/A
Peak Unit Inlet (°F):	69.7	32.0
Peak Unit Outlet (°F):	79.2	27.9
Total Unit Capacity (kBtu/Hr):	480.0	385.0
Peak Load (kBtu/Hr):	480.0	385.0
Peak Demand (kW):	31.7	29.9
Heat Pump EER/COP:	15.1	3.8
Seasonal Heat Pump EER/COP:	19.2	3.8
Avg. Annual Power (kWh):	1.44E+4	5.87E+4
System Flow Rate (gpm):	120.0	96.3

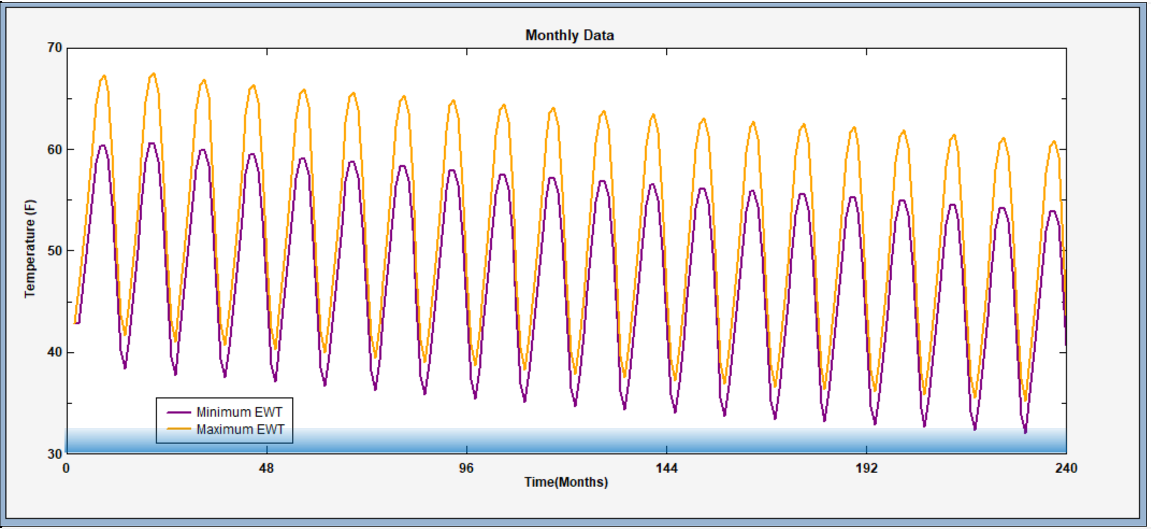


Further increasing the size of the GHX for the church

Further increasing total borehole length to 10,920’ (273’ / ton) doesn’t eliminate long term temperature degradation…it simply delays the inevitable.

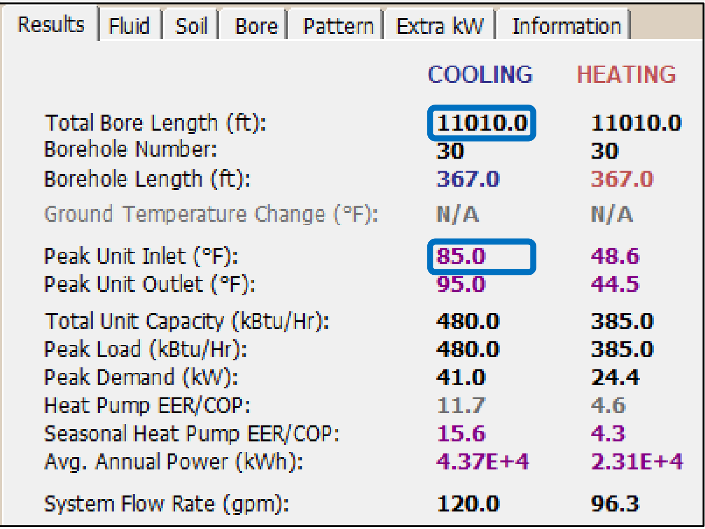


	COOLING	HEATING
Total Bore Length (ft):	10920.0	10920.0
Borehole Number:	30	30
Borehole Length (ft):	364.0	364.0
Ground Temperature Change (°F):	N/A	N/A
Peak Unit Inlet (°F):	67.5	32.0
Peak Unit Outlet (°F):	77.0	27.9
Total Unit Capacity (kBtu/Hr):	480.0	385.0
Peak Load (kBtu/Hr):	480.0	385.0
Peak Demand (kW):	30.6	29.9
Heat Pump EER/COP:	15.6	3.8
Seasonal Heat Pump EER/COP:	19.6	3.8
Avg. Annual Power (kWh):	1.41E+4	5.90E+4
System Flow Rate (gpm):	120.0	96.3

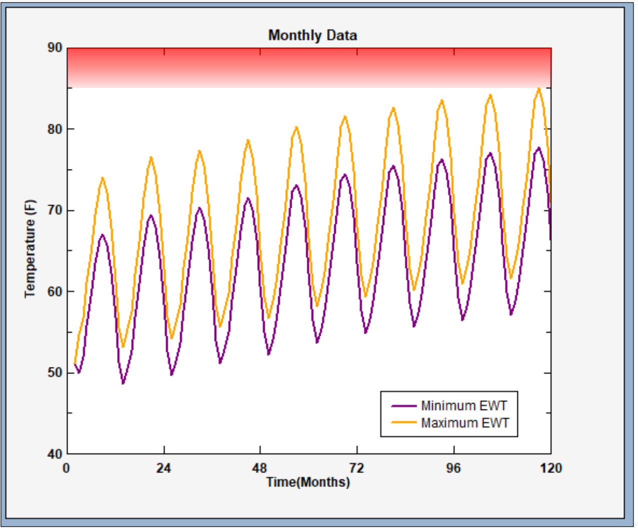


Increasing the size of the GHX for retail project

Increasing the size of the GHX from 8,000’ of borehole to 11,010’ (275’ / ton) extends the length of time till the temperature of the GHX rises outside of efficient operating parameters…but doesn’t stop long term temperature degradation.

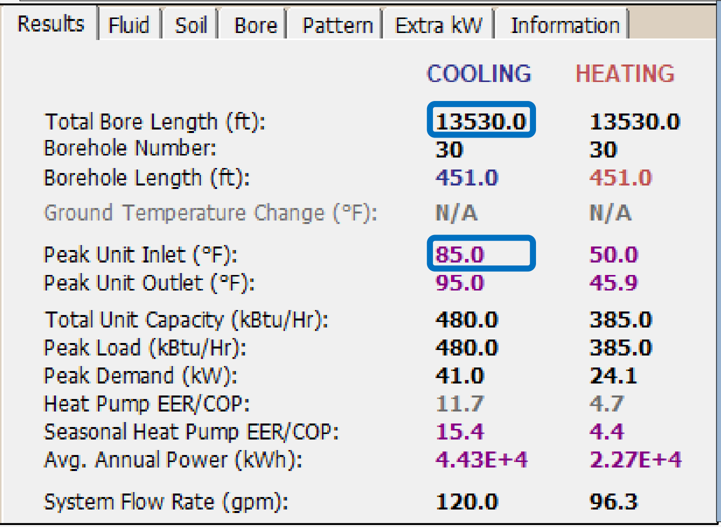


	COOLING	HEATING
Total Bore Length (ft):	11010.0	11010.0
Borehole Number:	30	30
Borehole Length (ft):	367.0	367.0
Ground Temperature Change (°F):	N/A	N/A
Peak Unit Inlet (°F):	85.0	48.6
Peak Unit Outlet (°F):	95.0	44.5
Total Unit Capacity (kBtu/Hr):	480.0	385.0
Peak Load (kBtu/Hr):	480.0	385.0
Peak Demand (kW):	41.0	24.4
Heat Pump EER/COP:	11.7	4.6
Seasonal Heat Pump EER/COP:	15.6	4.3
Avg. Annual Power (kWh):	4.37E+4	2.31E+4
System Flow Rate (gpm):	120.0	96.3

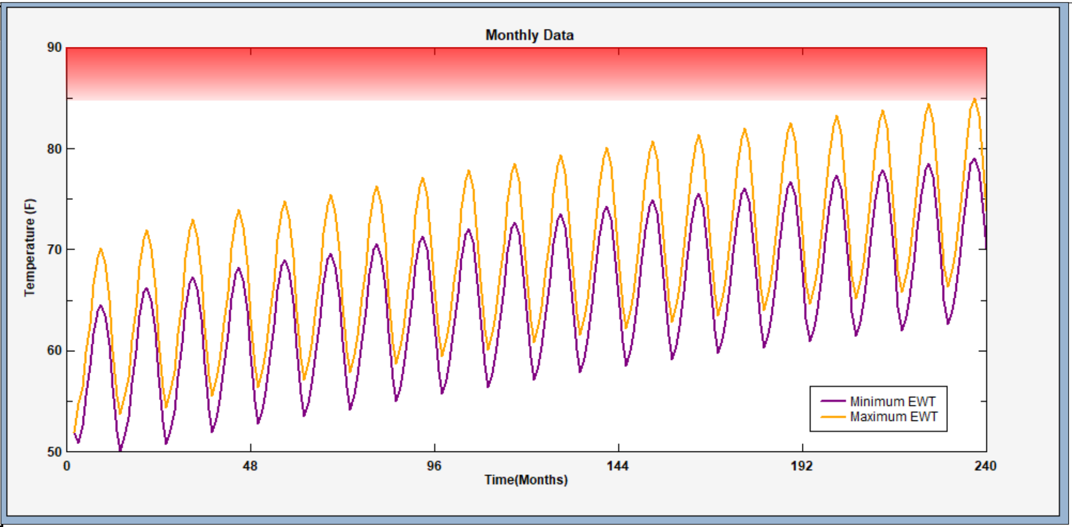


Further increasing the size of GHX for retail project

Further increasing the amount of borehole for the retail project to 13,530’ (338’ / ton) doesn’t eliminate long term temperature degradation…simply delays it.

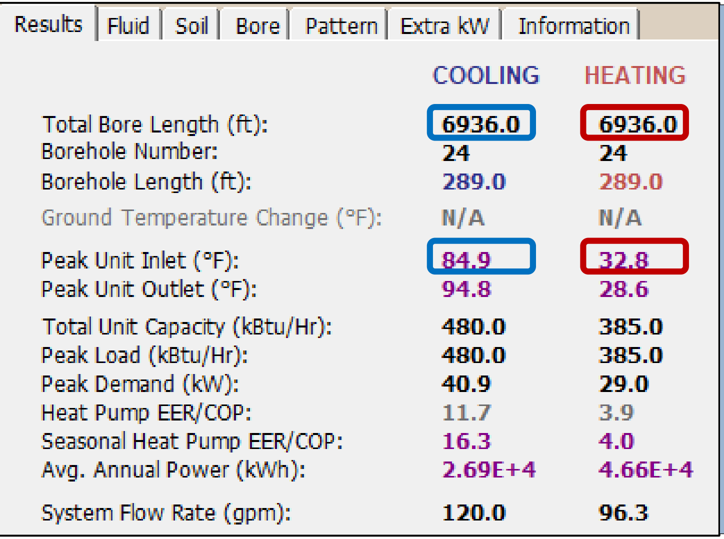


	COOLING	HEATING
Total Bore Length (ft):	13530.0	13530.0
Borehole Number:	30	30
Borehole Length (ft):	451.0	451.0
Ground Temperature Change (°F):	N/A	N/A
Peak Unit Inlet (°F):	85.0	50.0
Peak Unit Outlet (°F):	95.0	45.9
Total Unit Capacity (kBtu/Hr):	480.0	385.0
Peak Load (kBtu/Hr):	480.0	385.0
Peak Demand (kW):	41.0	24.1
Heat Pump EER/COP:	11.7	4.7
Seasonal Heat Pump EER/COP:	15.4	4.4
Avg. Annual Power (kWh):	4.43E+4	2.27E+4
System Flow Rate (gpm):	120.0	96.3

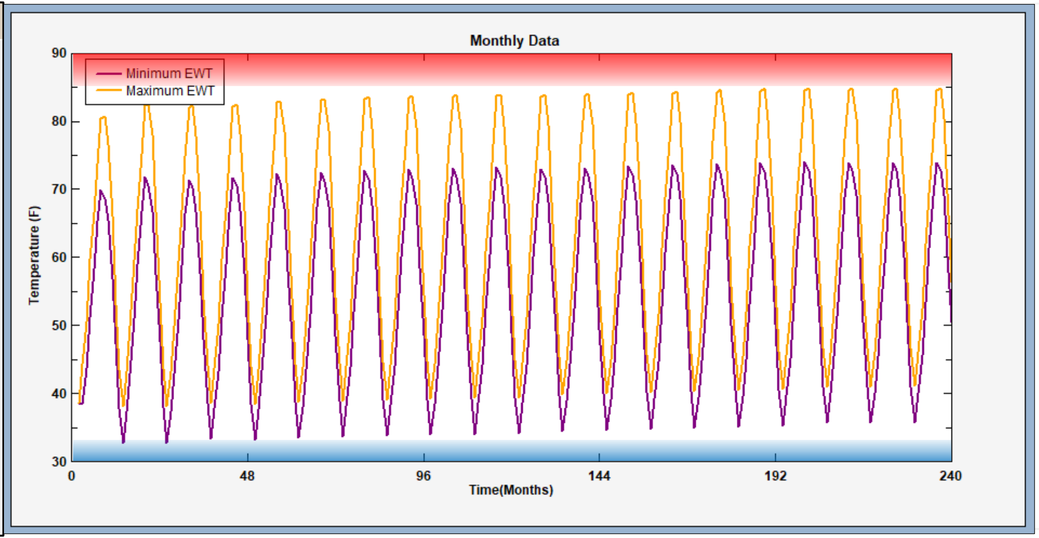


Calculated size of GHX for apartment building

The amount of energy rejected to the GHX from the apartment building while cooling is approximately equal to the energy extracted when heating…the loads to and from the ground are balanced year after year…eliminating long term temperature degradation. The size of the GHX can be reduced when the loads are balanced.



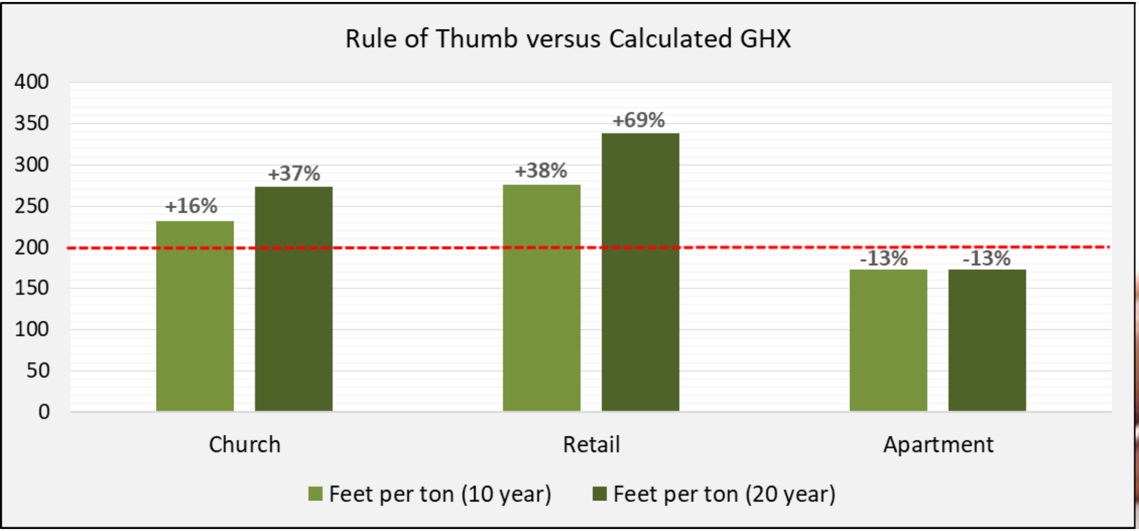
	COOLING	HEATING
Total Bore Length (ft):	6936.0	6936.0
Borehole Number:	24	24
Borehole Length (ft):	289.0	289.0
Ground Temperature Change (°F):	N/A	N/A
Peak Unit Inlet (°F):	84.9	32.8
Peak Unit Outlet (°F):	94.8	28.6
Total Unit Capacity (kBtu/Hr):	480.0	385.0
Peak Load (kBtu/Hr):	480.0	385.0
Peak Demand (kW):	40.9	29.0
Heat Pump EER/COP:	11.7	3.9
Seasonal Heat Pump EER/COP:	16.3	4.0
Avg. Annual Power (kWh):	2.69E+4	4.66E+4
System Flow Rate (gpm):	120.0	96.3



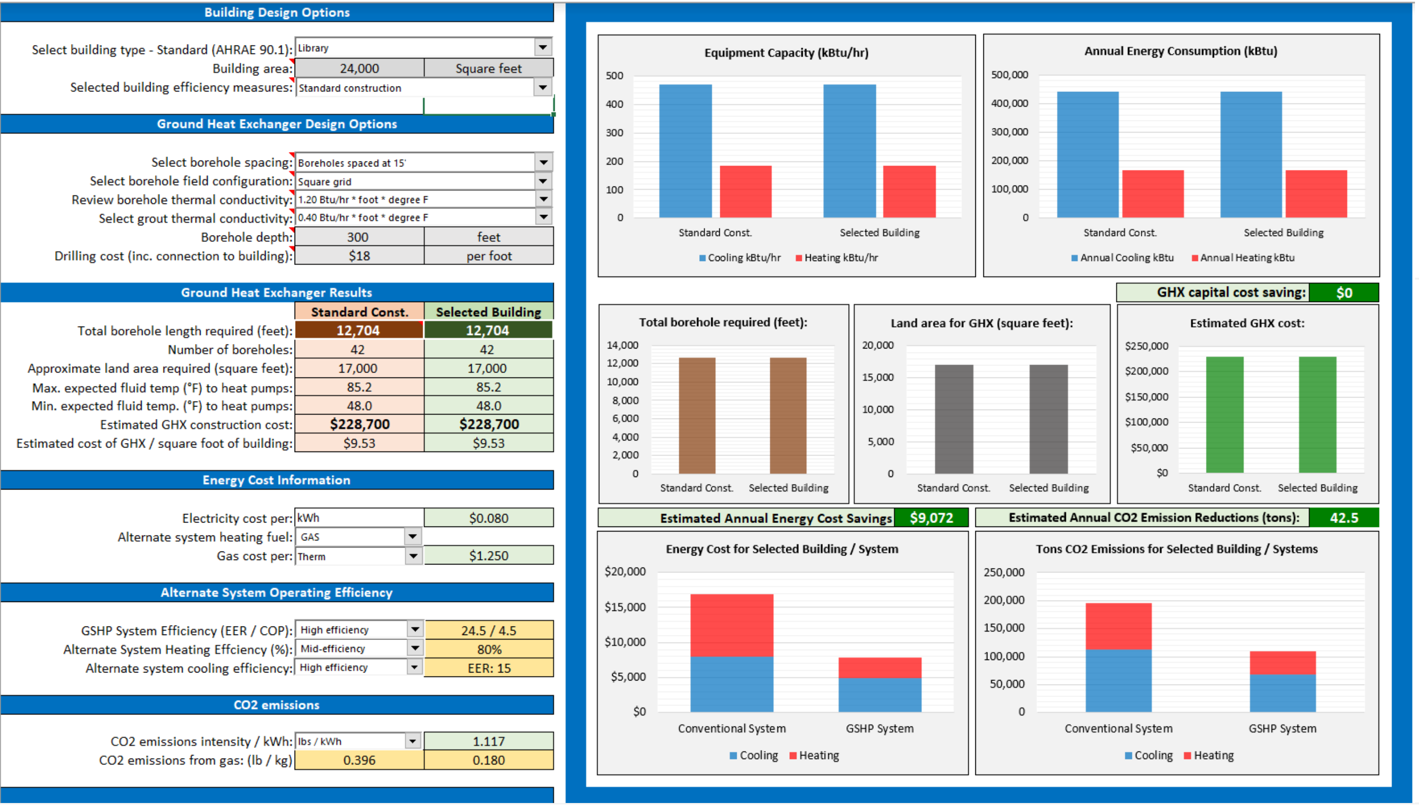
Problems resulting from using Rules of Thumb

Rules of thumb can result in projects that either:

- Fail because of long term temperature degradation, or
- Are not built because they are too expensive to build



Geothermal feasibility assessment tool



Building Design Options

Select building type - Standard (AHRAE 90.1):	Library	
Building area:	24,000	Square feet
Selected building efficiency measures:	Standard construction	

Ground Heat Exchanger Design Options

Select borehole spacing:	Boreholes spaced at 15'	
Select borehole field configuration:	Square grid	
Review borehole thermal conductivity:	1.20 Btu/hr * foot * degree F	
Select grout thermal conductivity:	0.40 Btu/hr * foot * degree F	
Borehole depth:	300	feet
Drilling cost (inc. connection to building):	$18	per foot

Ground Heat Exchanger Results

	Standard Const.	Selected Building
Total borehole length required (feet):	12,704	12,704
Number of boreholes:	42	42
Approximate land area required (square feet):	17,000	17,000
Max. expected fluid temp (°F) to heat pumps:	85.2	85.2
Min. expected fluid temp. (°F) to heat pumps:	48.0	48.0
Estimated GHX construction cost:	$228,700	$228,700
Estimated cost of GHX / square foot of building:	$9.53	$9.53

Energy Cost Information

Electricity cost per:	kWh	$0.080
Alternate system heating fuel:	GAS	
Gas cost per:	Therm	$1.250

Alternate System Operating Efficiency

GSHP System Efficiency (EER / COP):	High efficiency	24.5 / 4.5
Alternate System Heating Effciency (%):	Mid-efficiency	80%
Alternate system cooling efficiency:	High efficiency	EER: 15

CO2 emissions

CO2 emissions intensity / kWh:	lbs / kWh	1.117
CO2 emissions from gas: (lb / kg)	0.396	0.180

GHX capital cost saving: $0

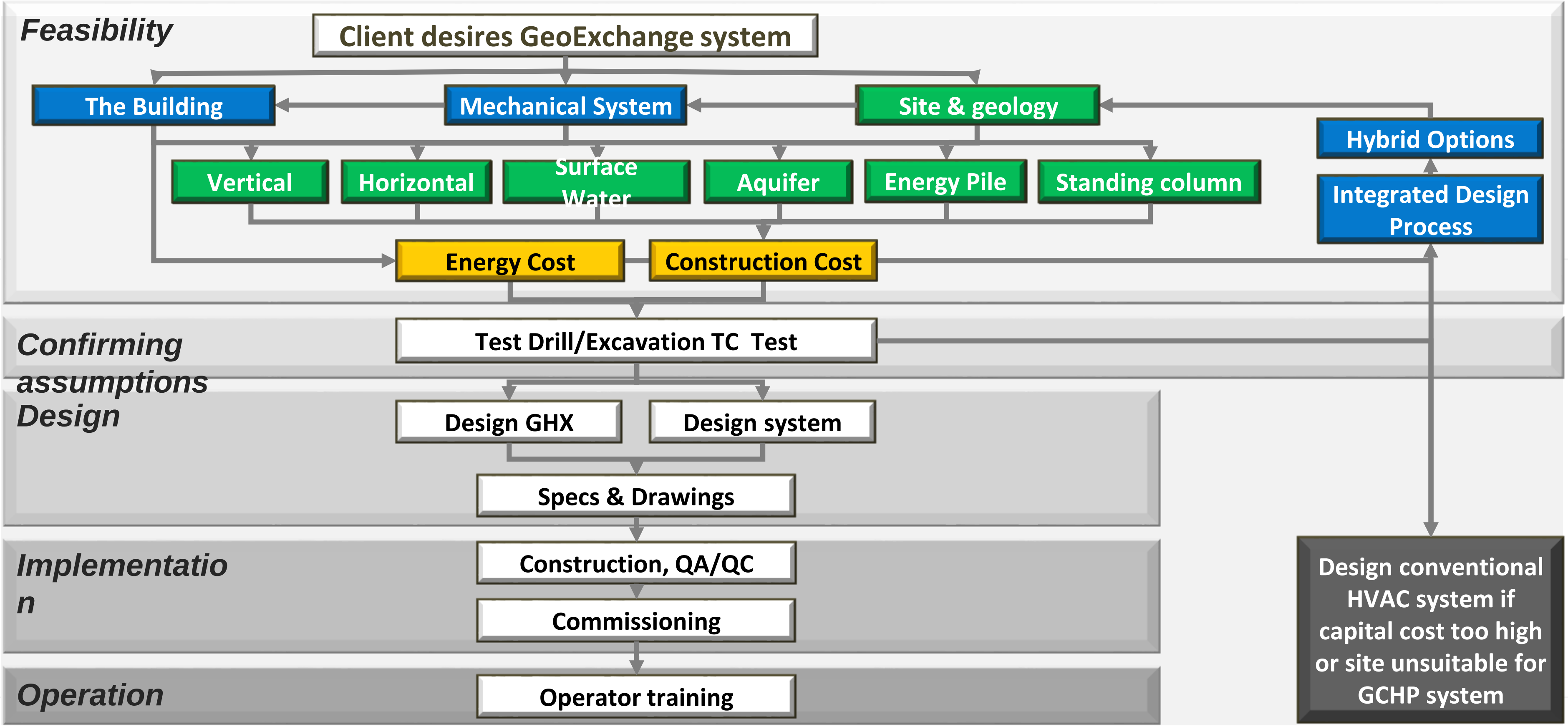
Estimated Annual Energy Cost Savings $9,072

Estimated Annual CO2 Emission Reductions (tons): 42.5

Estimate the size & cost of a GHX in minutes based on the:

- Building type
- Building size
- Building construction
- Location
- Geology
- GHX configuration
- GHX design

Ground heat exchanger optimization



Feasibility

Client desires GeoExchange system

The Building

Mechanical System

Site & geology

Hybrid Options

Vertical

Horizontal

Surface Water

Aquifer

Energy Pile

Standing column

Integrated Design Process

Energy Cost

Construction Cost

Confirming assumptions

Test Drill/Excavation TC Test

Design

Design GHX

Design system

Specs & Drawings

Implementation

Construction, QA/QC

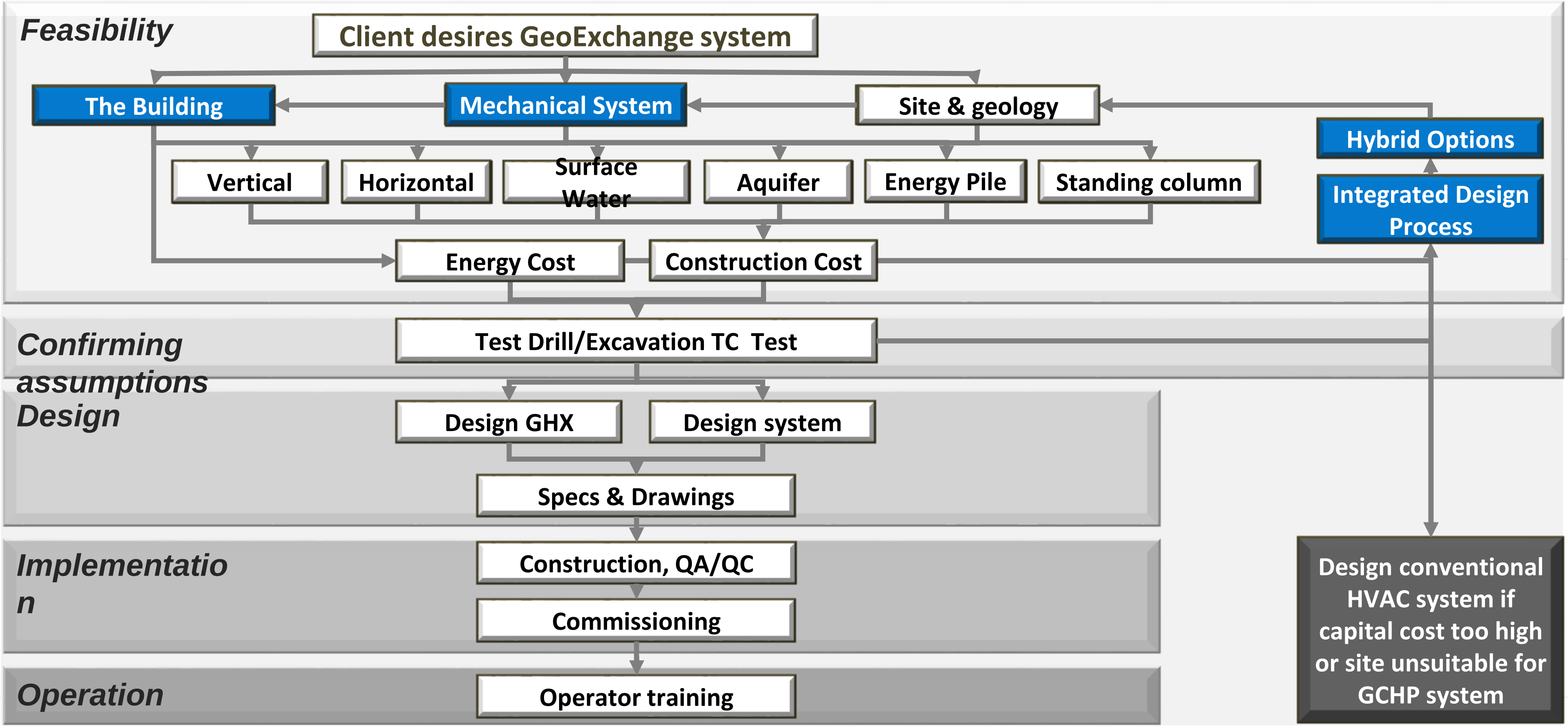
Commissioning

Operation

Operator training

Design conventional HVAC system if capital cost too high or site unsuitable for GCHP system

Ground heat exchanger optimization



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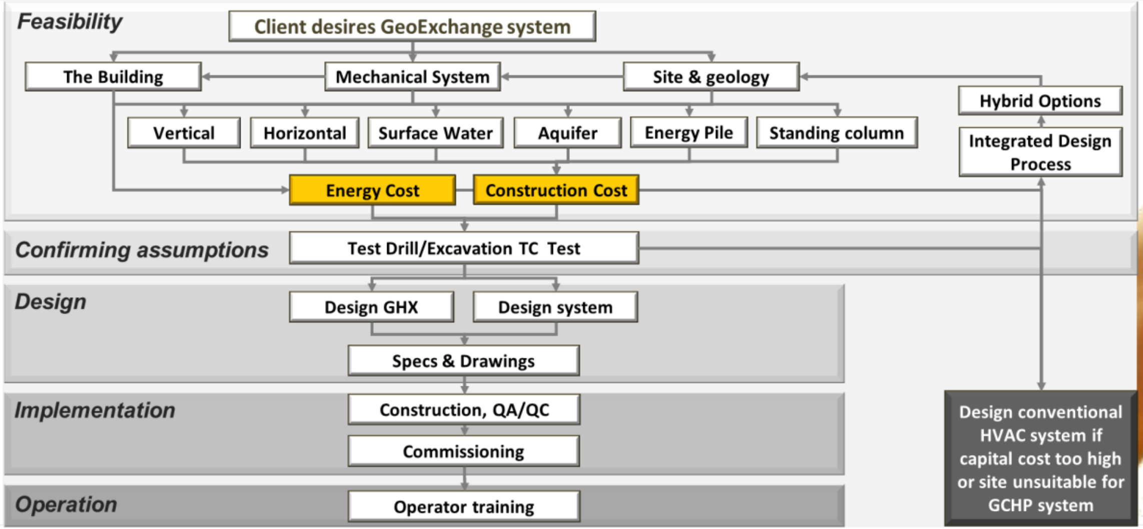
It’s all about the money all of the time

Most people considering a GSHP system in their project ask: “Will a GSHP system save enough money to provide a reasonable return on my investment?”



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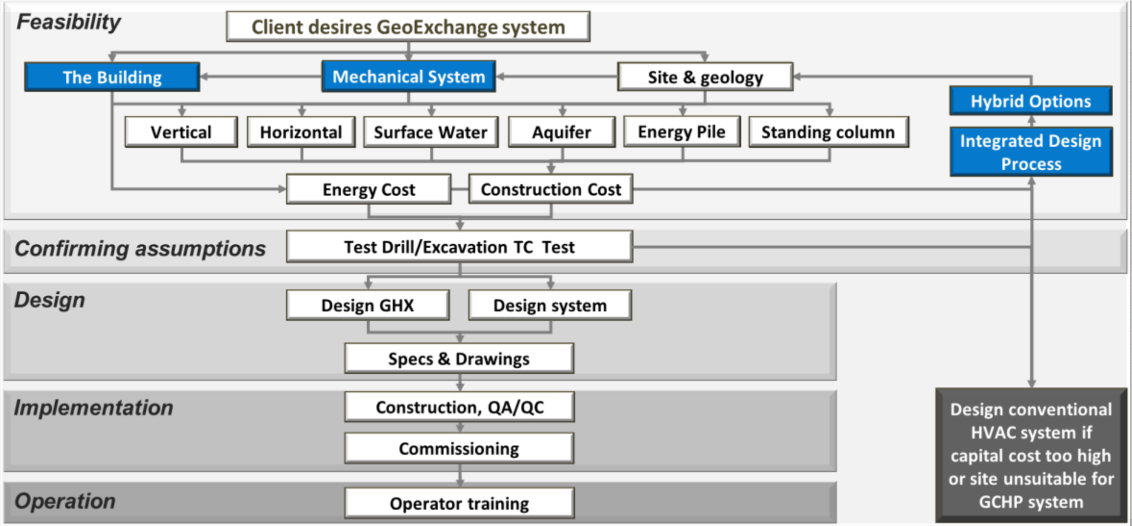
Influencing building design

If you can influence the design of the building the:

- Building energy loads change,
- Performance of the ground heat exchanger will change, and
- Size and cost of the ground heat exchanger changes…and economics improves



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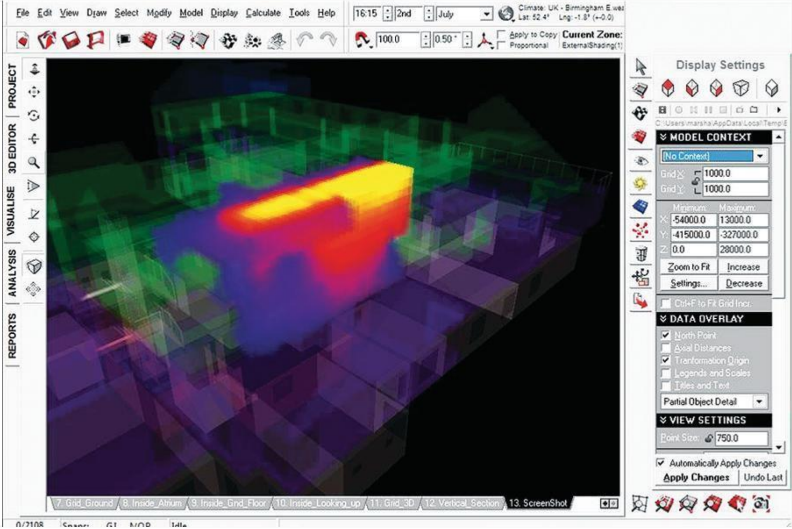


Building design

Building energy loads are influenced by factors such as the:

- Roof design
- Window specifications
- Lighting specifications

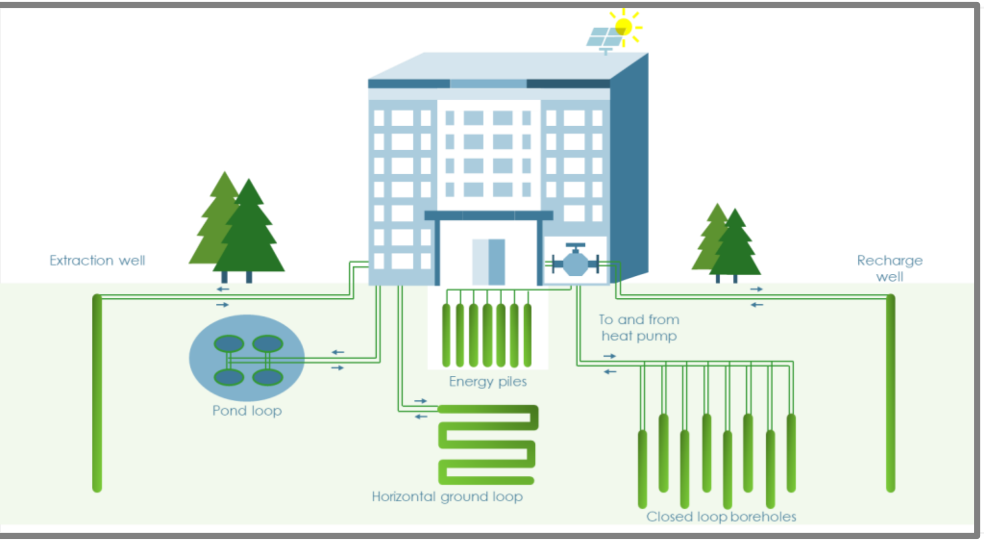
Mechanical system design

Mechanical system design influences building energy loads:

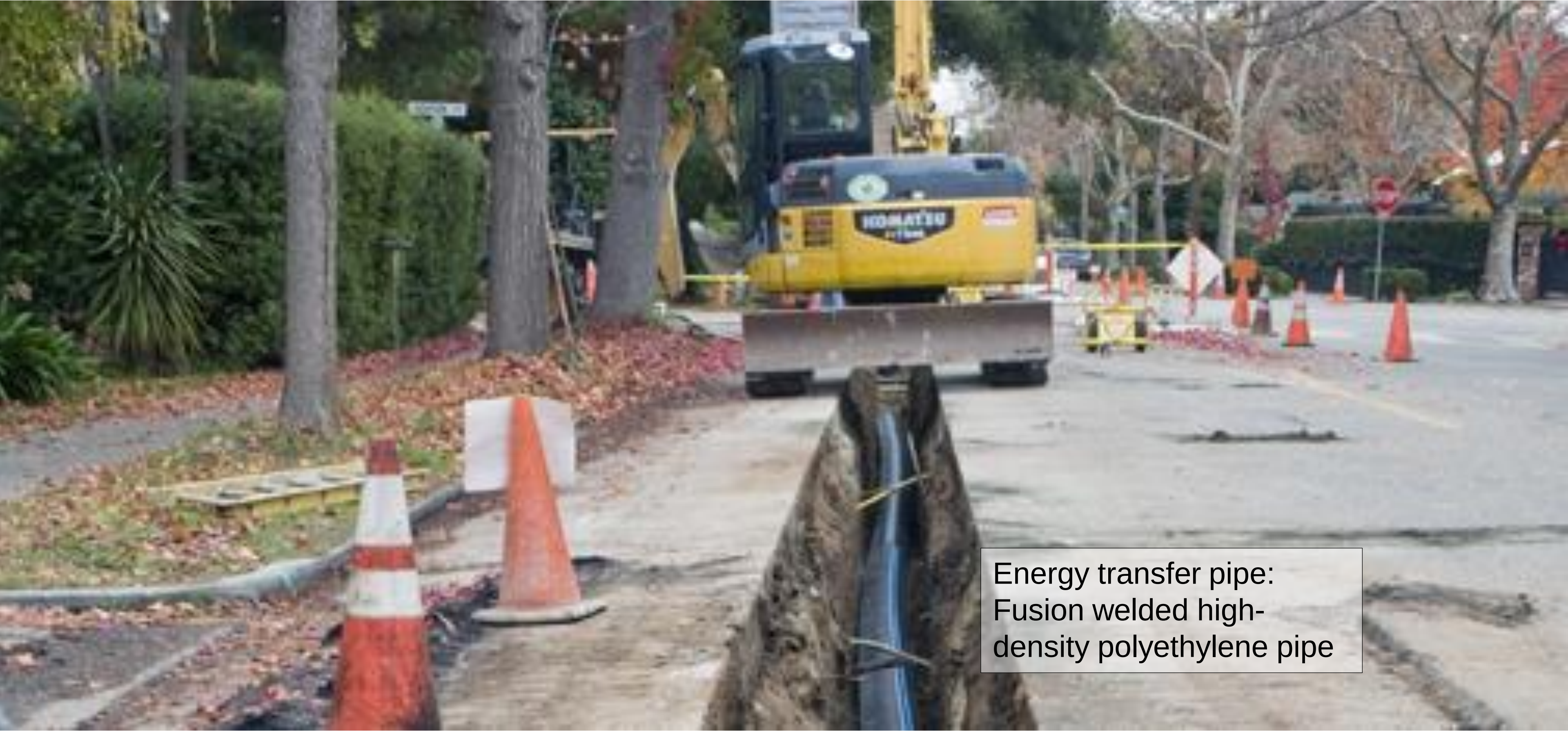
- Ventilation air strategy (energy recovery, demand ventilation, economizer)
- Cooling with warmer temperatures (chilled beams, floors)
- Heating with cooler temperatures (radiant floors)

Geo is an opportunistic technology

Working with the client and design team and taking advantage of unique opportunities on a site helps improve the economics of installing a ground source heat pump system.



Moving energy from building to building



Energy transfer pipe: Fusion welded high-density polyethylene pipe

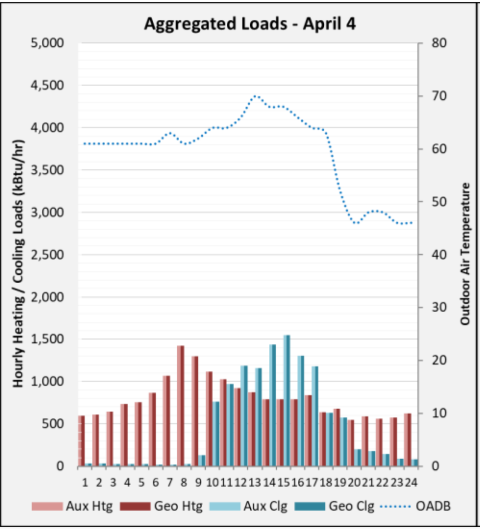
District geothermal energy system take advantage of diversity

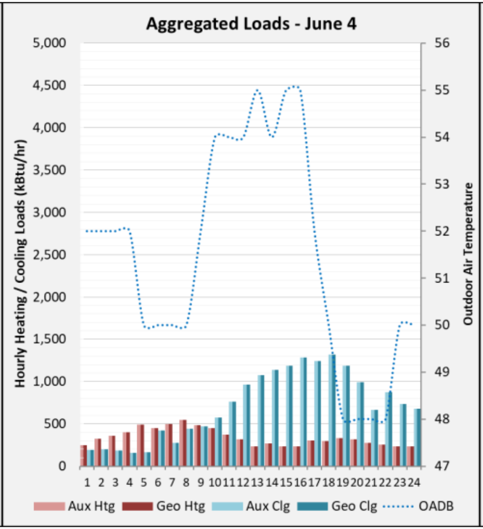
A district geothermal system transfers energy between buildings. Different buildings operate differently…peak loads occur at different times of day, or on different days. Some buildings are cooling…rejecting heat…while others need heat.

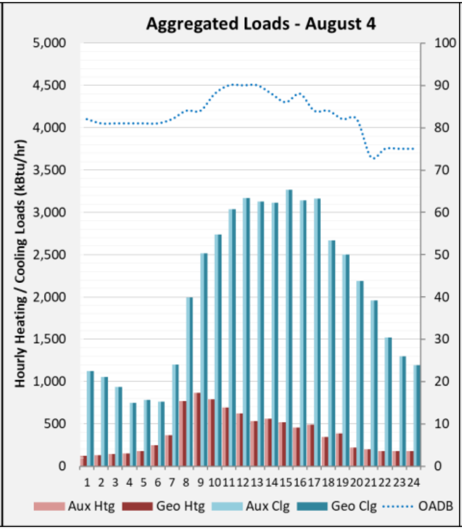
Sharing energy between buildings

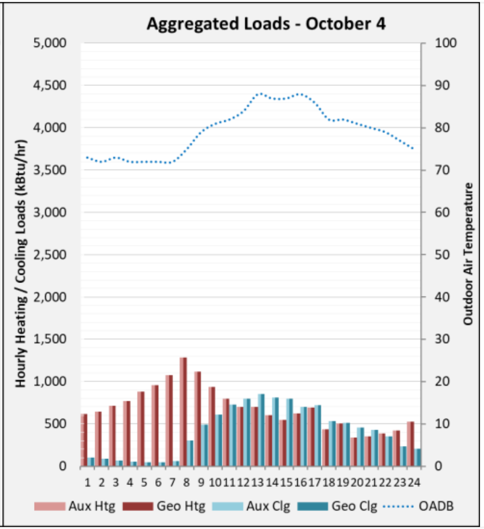
Connecting diverse building loads to a common system facilitates energy transfer from one building to another…recycling energy within the system rather than dissipating heat to the earth.

Sharing loads reduces the amount of GHX required.



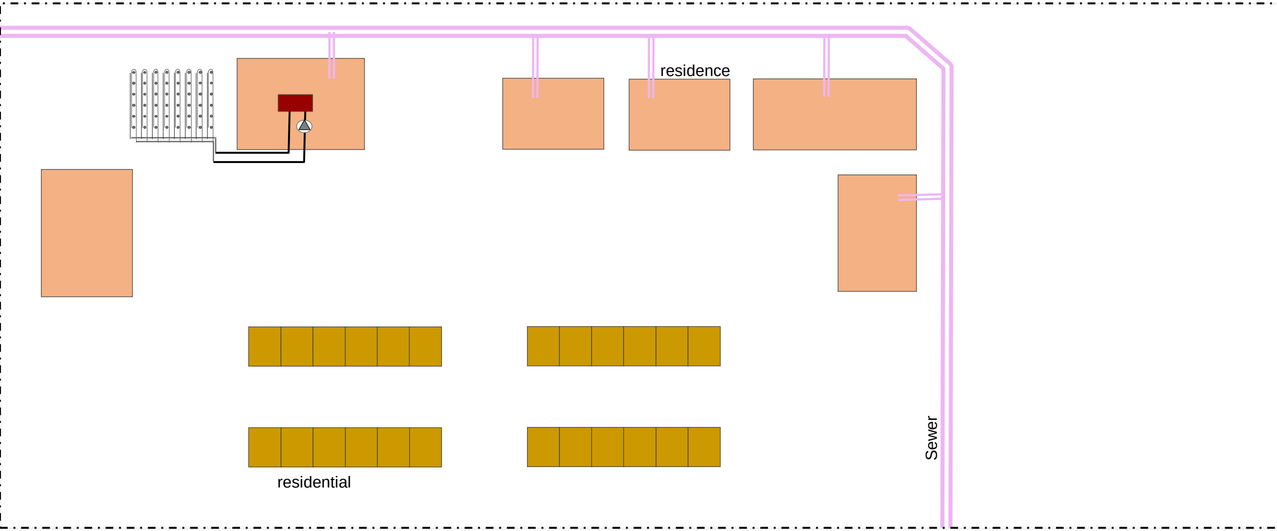






A GHX for one building – beginnings of a connected system

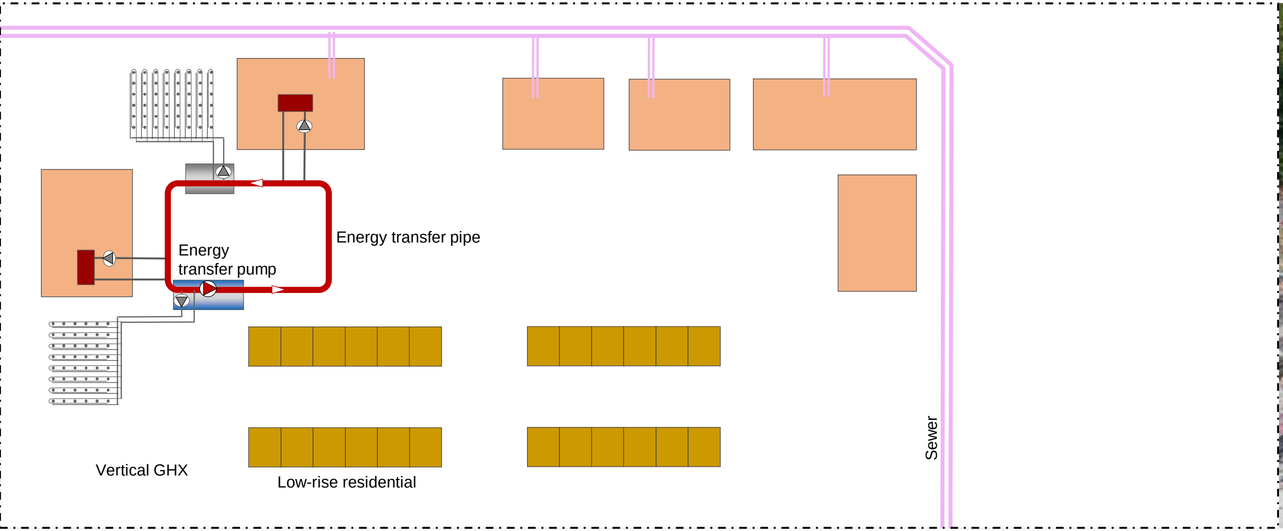
A connected energy sharing system can begin with a single building, either a building due for a mid-life retrofit or a new building. This can operate as a free-standing GSHP system.



Connecting a second building to a common GHX

A second GSHP system can be connected to the first by connecting both building systems and both GHX's to an "energy transfer pipe".

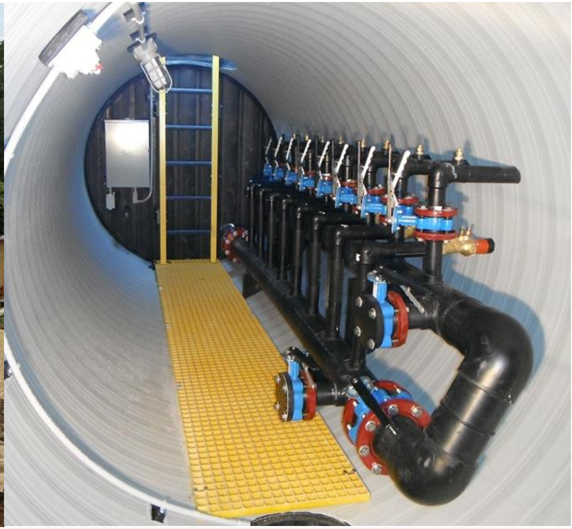
An energy transfer pipe is a single, uninsulated high-density polyethylene pipe and pump to move heat transfer fluid.



Manufactured pump stations

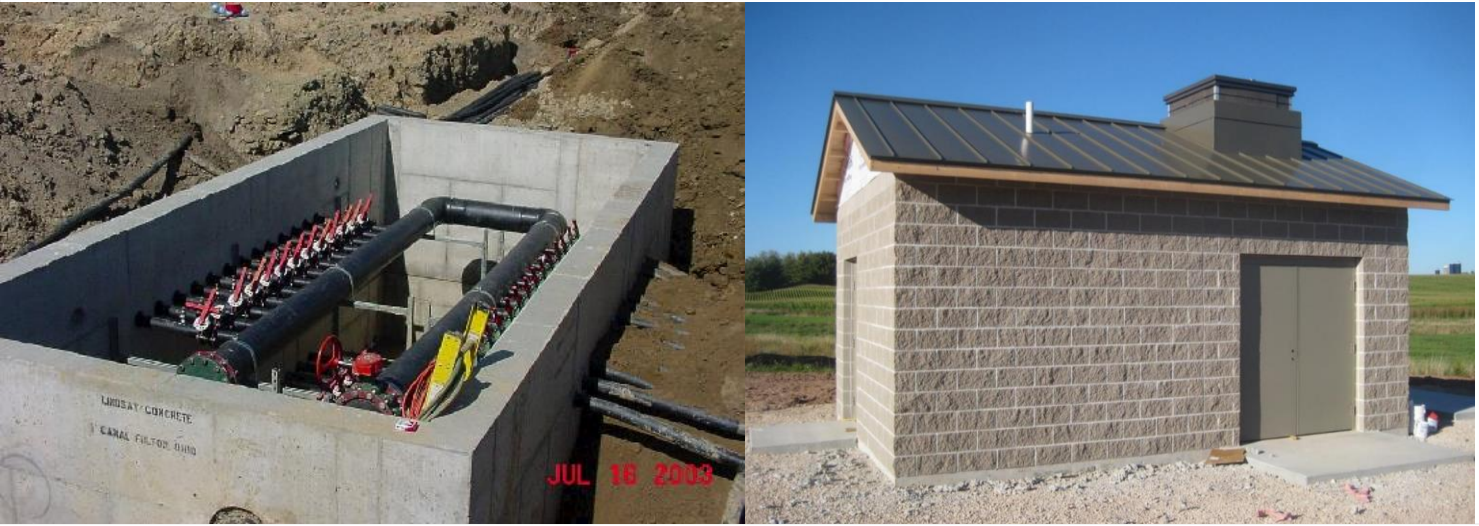
Several manufacturers offer manufactured pump stations to connect the energy transfer pipe to GHX modules.

Pre-manufactured HDPE vault



Purpose built pump stations

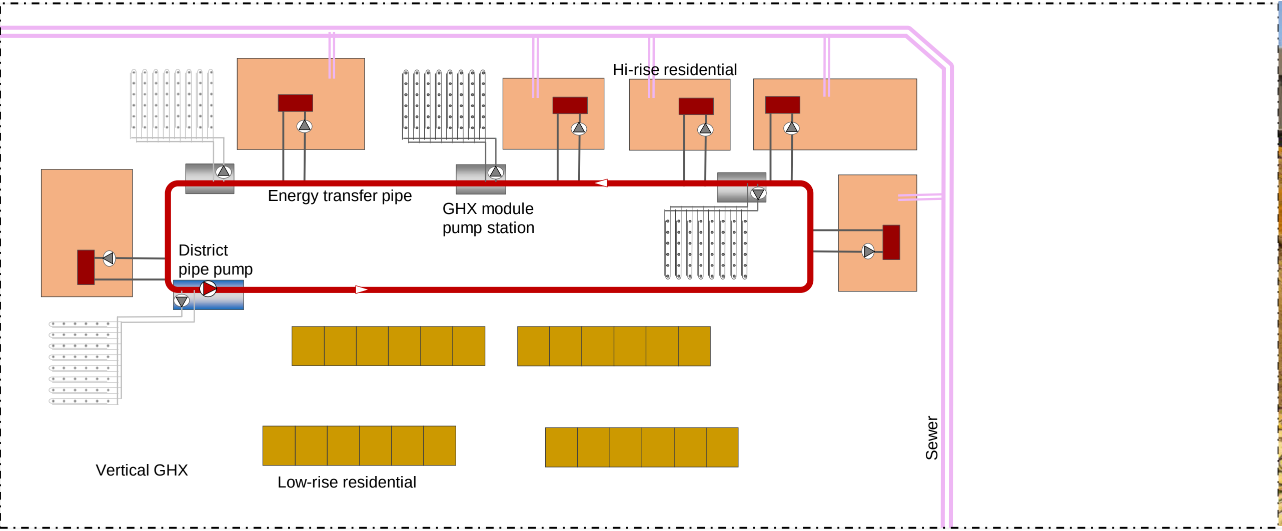
Pump stations can be constructed on site as required.



Expanding the system

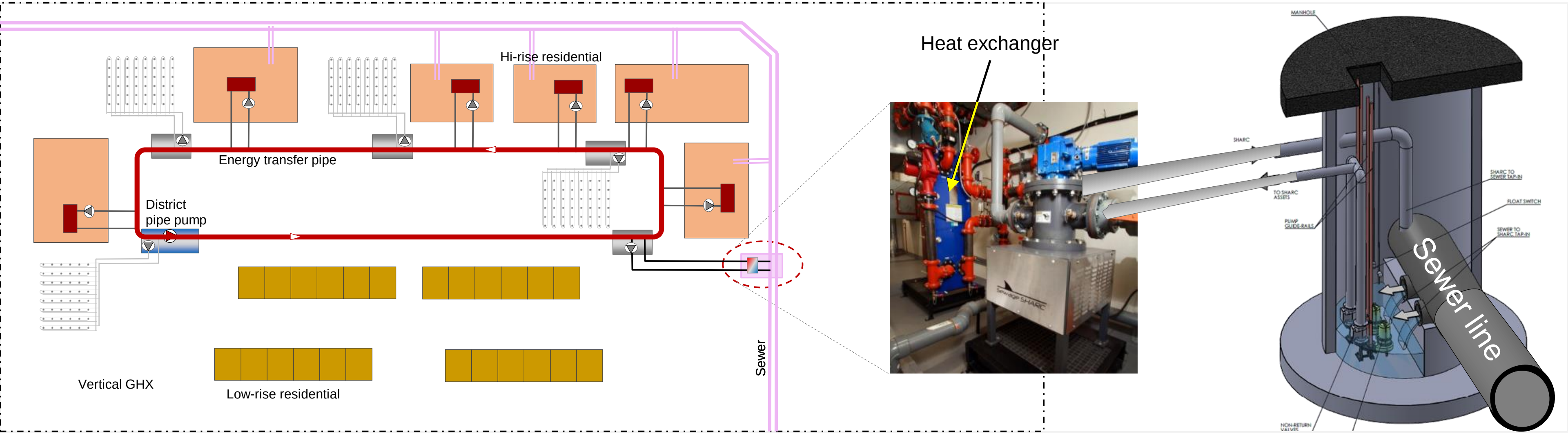
As major building retrofits or new buildings are planned the system can be expanded by connecting buildings to the energy transfer pipe and connecting new GHX modules as needed.

Any type of GHX configuration or wells can be added to the system depending on land area available and geological conditions.



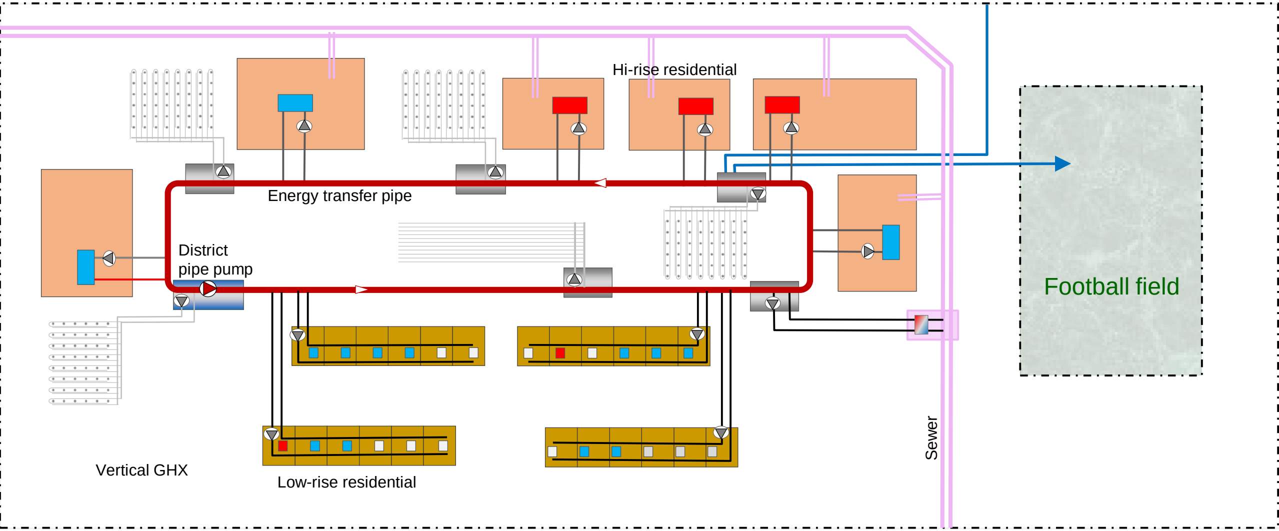
Waste water energy transfer

Waste water typically flows through sewers at 60-70°F. Energy from the system can be transferred to or from waste water, avoiding the cost of additional GHX modules.



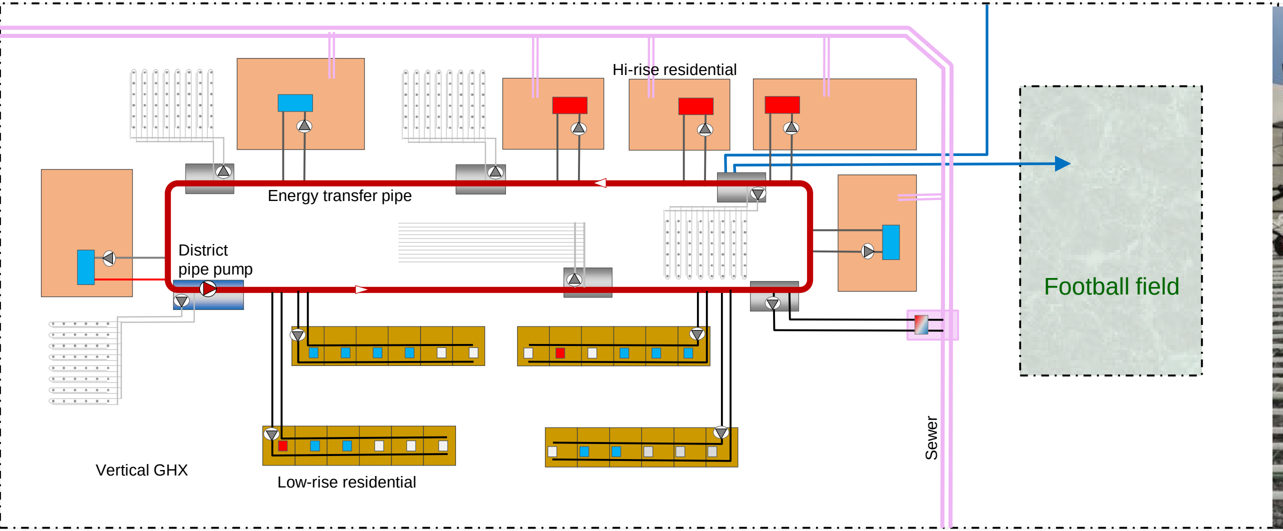
Dissipating heat with irrigation water

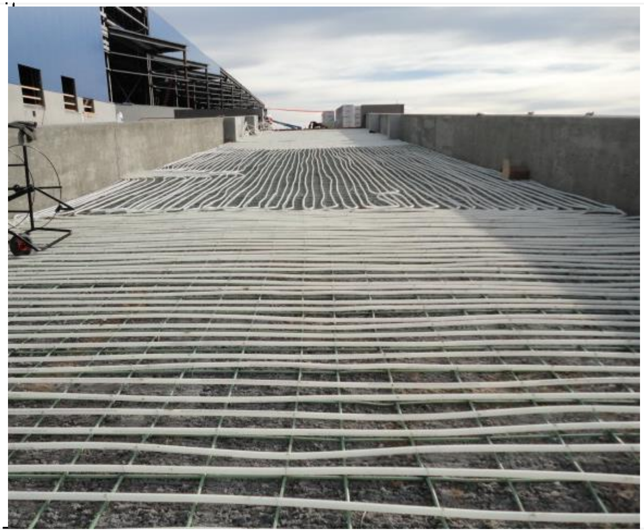
Irrigation water can be used to absorb energy from energy transfer pipe…reducing heat rejection to the ground and reducing the cost of building additional GHX modules. Additional heat sources / sinks allow addition of energy loads to the system.



Dissipating heat with snow melt systems

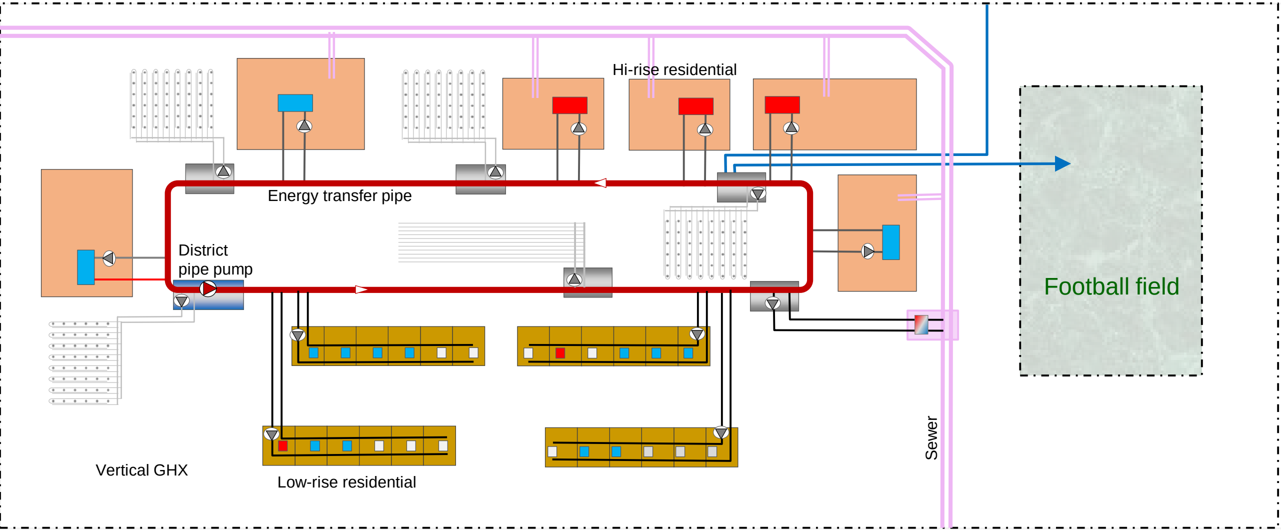
Snow melt on sidewalks and streets near buildings can offer a beneficial use for excess heat and can be used even in summer to dissipate excess heat from system if necessary.





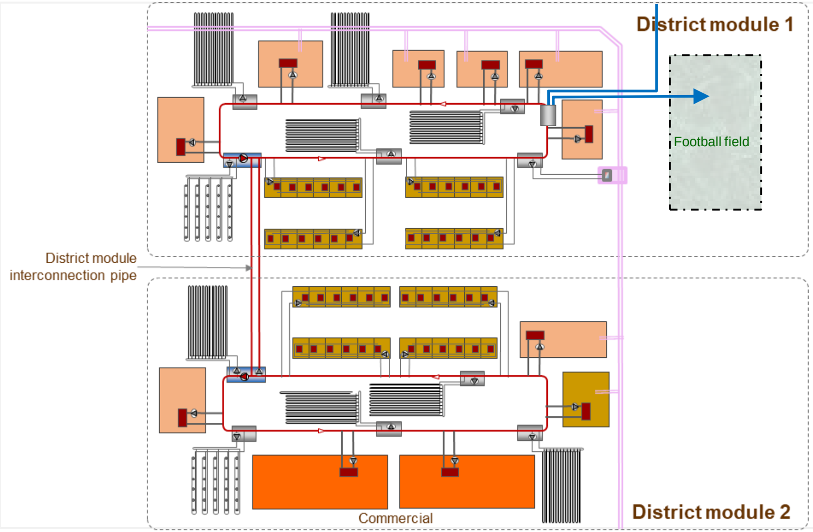
If no other beneficial use can be found…

A cooling tower can be added to a system if a beneficial use for excess heat in the system can't be found.

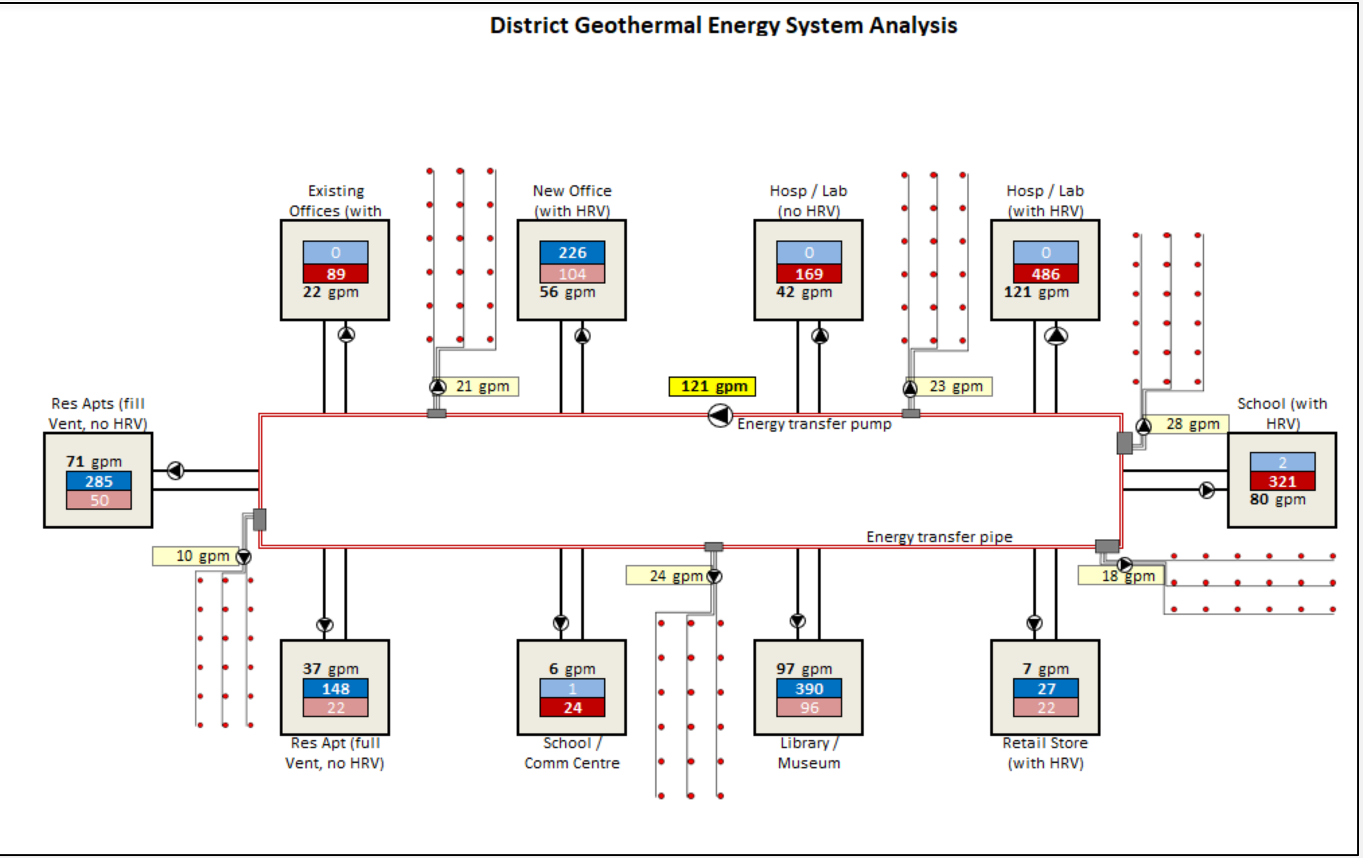


Expanding the district system

Additional district modules can be developed in adjacent neighborhoods. If a cooling dominant district is close to a heating dominant district, interconnection pipes between districts can transfer energy between them and both districts benefit with more moderate fluid temperatures.



Designing the greater system



Connecting building energy models to a larger system allows a designer to optimize the design of the overall system

The GeoMicroDistrict
Approach for a Utility-Scale
Transition to Clean Energy...

2019-10-28

Optimizing GSHP Systems for District Energy

Ed Lohrenz, BES, CGD

204-318-2156
ed@geoptimize.ca

GEOptimize.ca

The Thermal (Energy) Highway©

GreyEdge Group

Energy *harvested*, *moved*, and *reused*

Garen Ewbank, Garry Sexton, Cary Smith
801-942-6100
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gsexton@greyedgegroup.com
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#3 Distributed Energy Loops with Ground Coupled Heat Pump Systems

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“Community Convective Circulation Circuits©, (the 4 Cs©) also known as the “Thermal Highway©”

Roshan Revankar, Geo Design Engineer, Training Chair and Coordinator IGSHPA/Melink and Garry Sexton, Founding Director, The Grey Edge Group, LLC

- Design Team

(Left to Right)

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- Buncha Rathkaborias, Ho Chi Min City, Vietnam
- Denny Wang, Nanjing, China
- Leo Liu, Beijing, China
- Garry Sexton, Arkansas, USA
- Soung-ju Lee, Seoul, Korea
- Yunshic Choi, Busan, Korea

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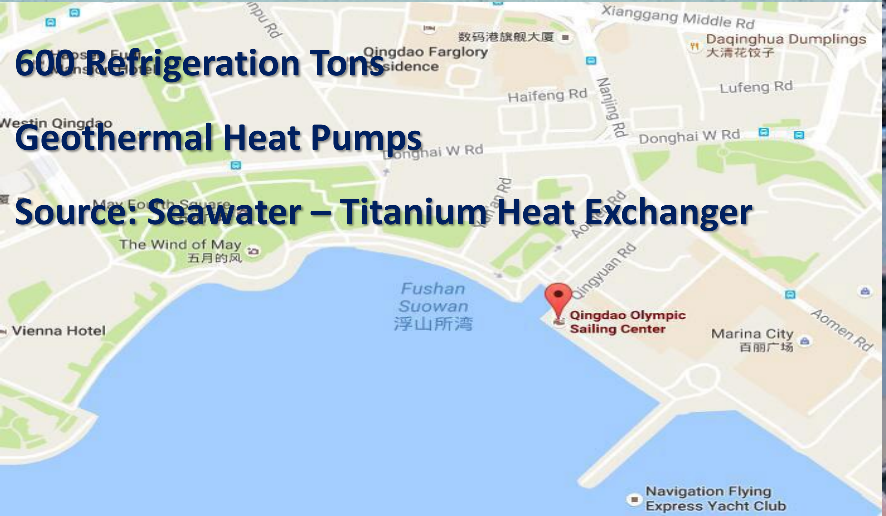
2008 Olympic Media Center, Qingdao, China

2008 Olympic Media Center, Qingdao, China



600 Refrigeration Tons

Geothermal Heat Pumps

Source: Seawater – Titanium Heat Exchanger

Art Farm Greenhouse, Busan, South Korea

Installation Date:

2009 Phase 1 of 6

Project Size:

2100 kW - 600 Refrigeration Tons

Geothermal Configuration:

Closed Loop – Vertical 35,000 Meter – 115,000 Feet

175 Boreholes 200 Meter – 660 Feet Depth

Building Footprint 100 By 200 Meters

GWACHEON NATIONAL SCIENCE MUSEUM, SEOUL, KOREA

- VERTICALLY DRILLED GEOTHERMAL SYSTEM
- 600 RT
- 200 VERTICAL BORES
- 200 METER (660 FEET) DEPTH
- 25% OF TOTAL LOAD

GWACHEON NATIONAL SCIENCE MUSEUM
SEOUL, KOREA

GWACHEON NATIONAL SCIENCE MUSEUM
SEOUL, KOREA

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SEOUL CITY HALL

- 1200 RT
- VERTICALLY DRILLED
- 200 METER (660 FEET)
- 400 BOREHOLES UNDER FOOTPRINT OF BUILDING
- DRILLED DURING BUILDING CONSTRUCTION

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SEOUL CITY HALL, SEOUL KOREA

Powered by R-718 Technology© - Courtesy of The GreyEdge Group© & IGSHPA

USAG HUMPHREYS

- UNDERGROUND COMMUNICATION CENTER
- 1200 COMPUTER RACKS
- ASIA LISTENING CENTER
- 5400 RT OF VERTICAL BORES
- N+2 PROJECT
- 230 & 330 METER DEPTH CLOSED LOOP BOREHOLES
- FULLY SELF CONTAINED

CY09 YRP A09Y601
COMMUNICATION CENTER, USAG HUMPHREYS, KOREA
C41010
기본과 원칙의 준수
Compliance with HSE Standards and Rules
ALWAYS
ALWAYS
한식뷔페
653-9363

US ARMY CORPS OF ENGINEERS COMMUNICATION CENTER PROJECT USAG CAMP HUMPHREYS, PYEONTAEK, KOREA

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USAG HUMPHREYS

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LOTTE TOWER, JAMSIL, SEOUL, KOREA

- 555 METER HEIGHT (1830 FEET)
- 123 STORY MIXED USE BUILDING
- OFFICES, APARTMENTS, RETAIL, FITNESS CENTERS, RESTAURANTS, NIGHT CLUBS
- 1100 VERTICAL BORES 200 METER DEPTH
- GEOTHERMAL 8000 RT FROM 3 SOURCES
- 3500 RT CLOSED LOOP VERTICAL, 3500 RT MUNICIPAL WATER, 1000 RT WASTE WATER
- GEOTHERMAL SYSTEM IS APPX. 30% OF TOTAL BUILDING LOAD AND SUPPLIES OVER 70% OF TOTAL HEATING, COOLING ANNUAL HOURS
- ALL GEOTHERMAL BOREHOLES WERE DRILLED UNDER FOOTPRINT OF BUILDING

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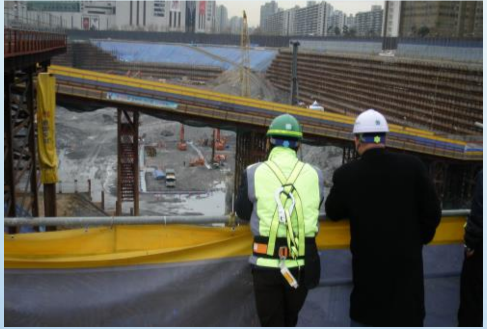
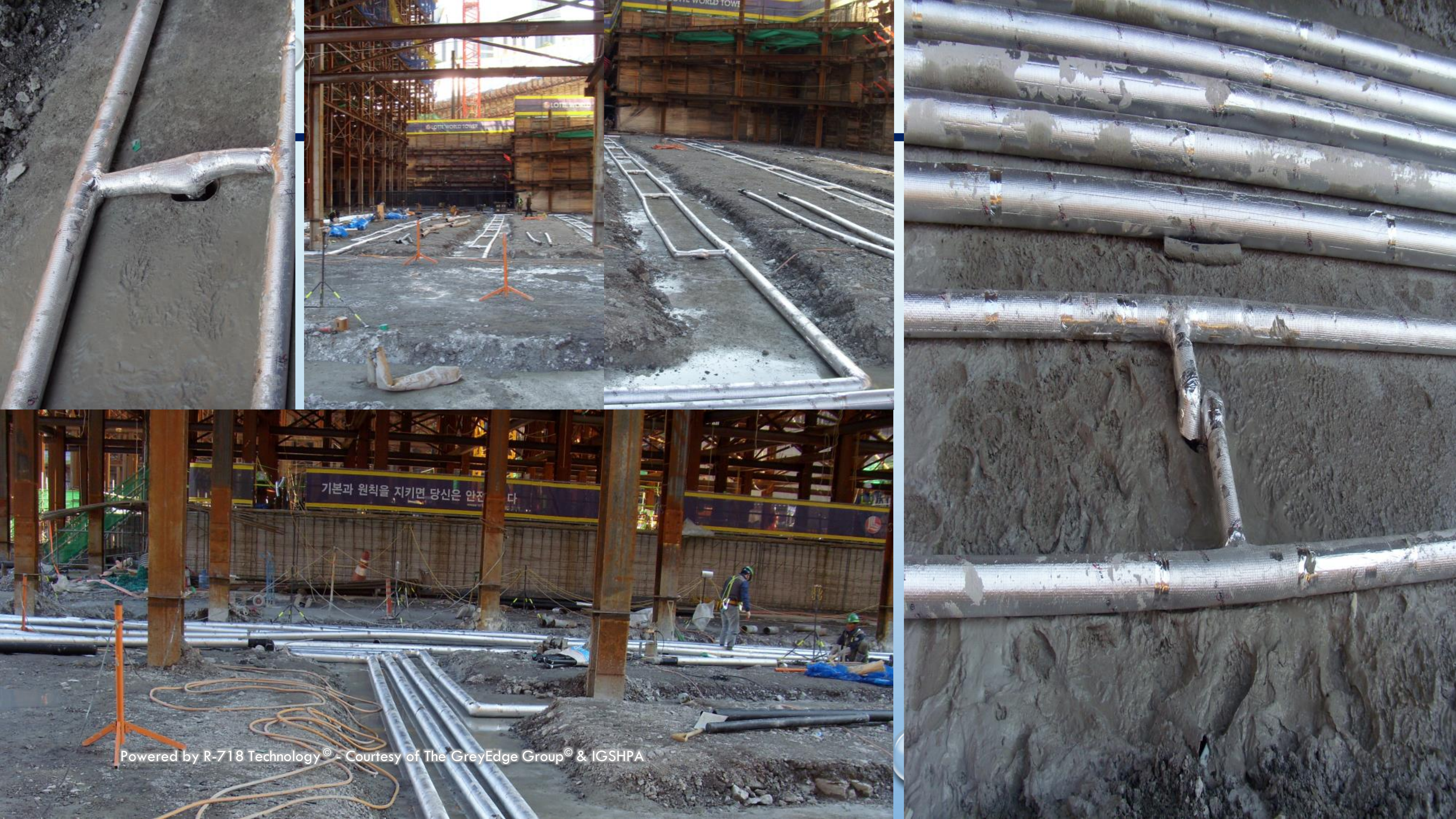


10/31/2019



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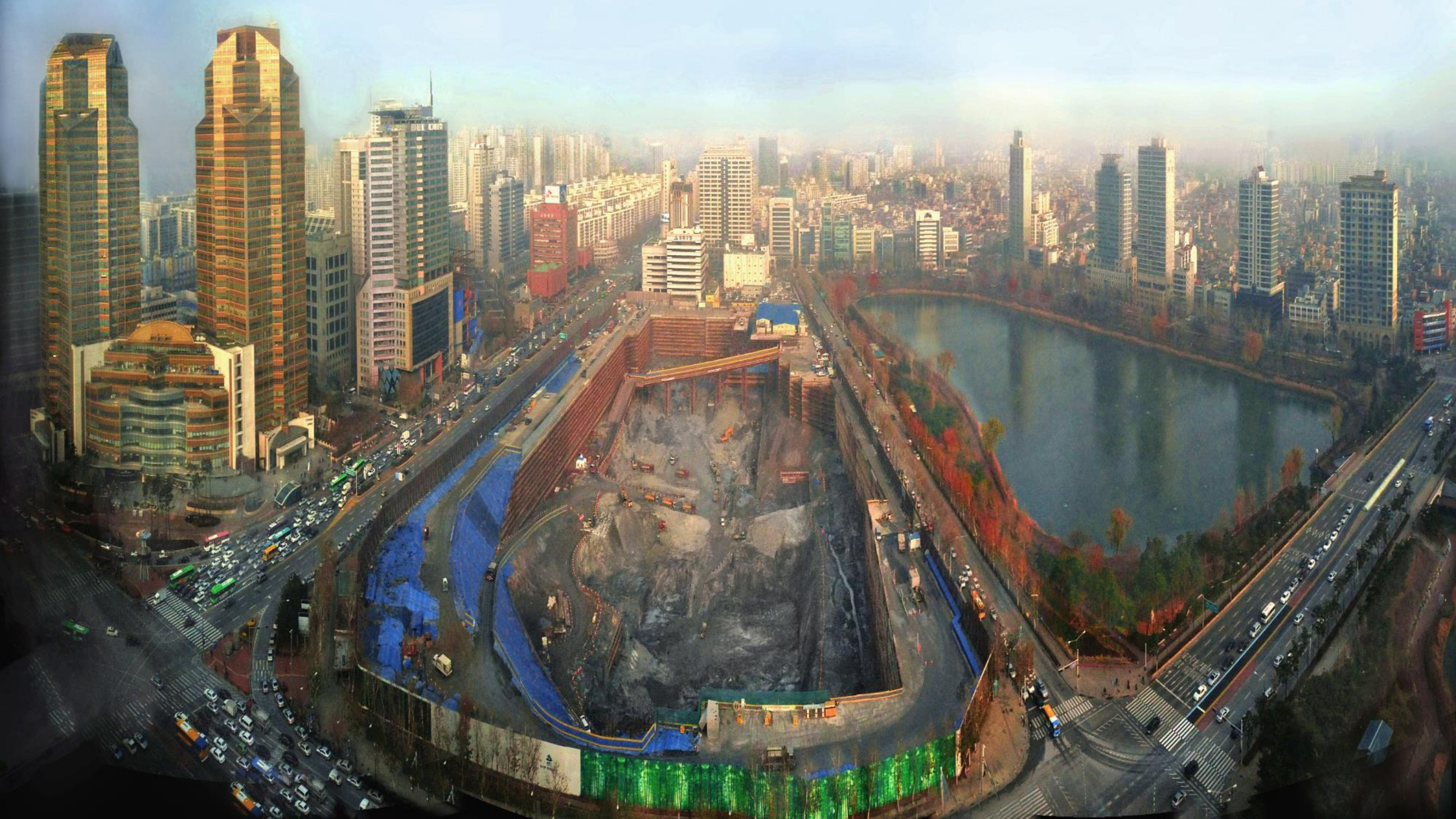
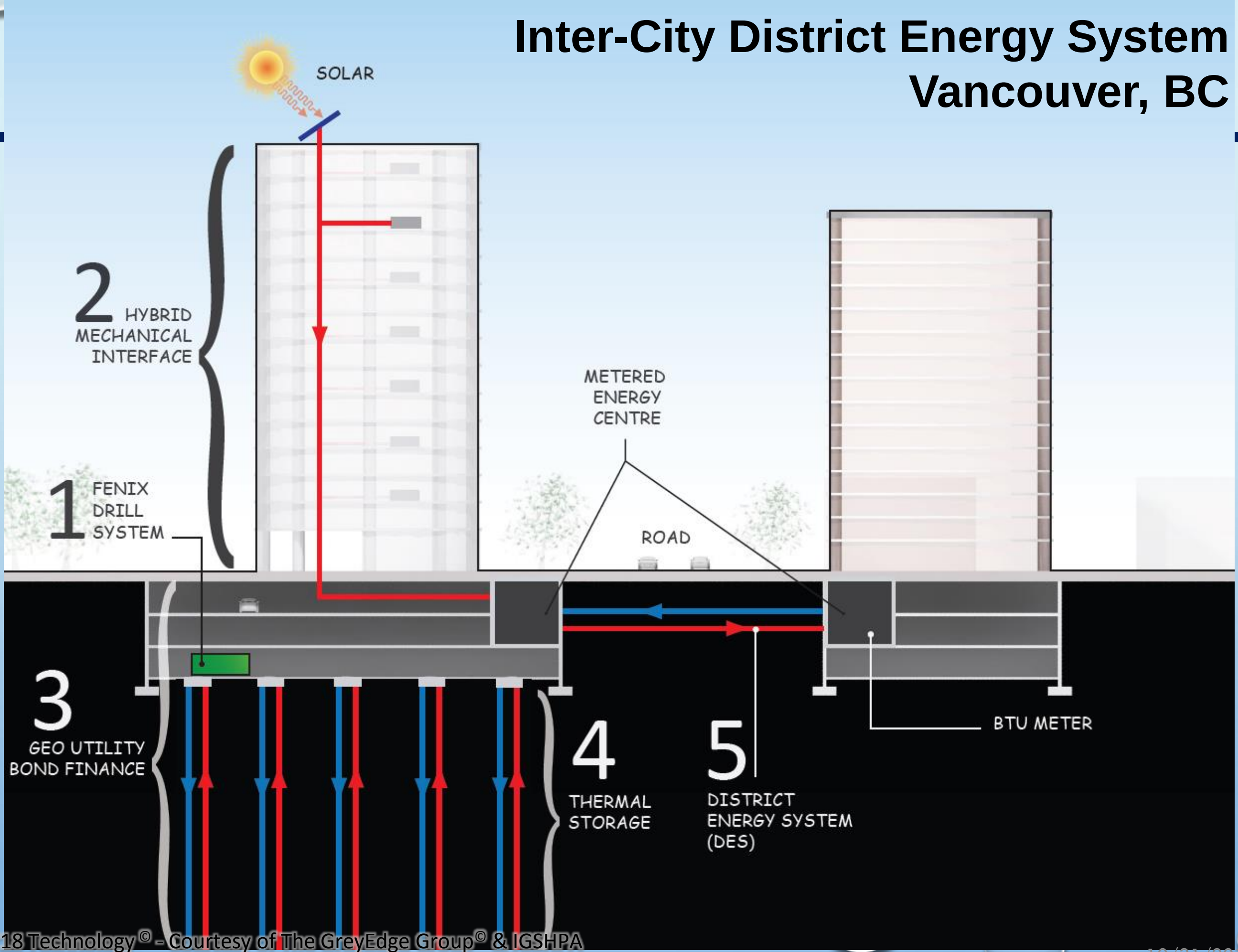


Inter-City District Energy System
Vancouver, BC


SOLAR
2 HYBRID MECHANICAL INTERFACE
1 FENIX DRILL SYSTEM
METERED ENERGY CENTRE
ROAD
3 GEO UTILITY BOND FINANCE
4 THERMAL STORAGE
5 DISTRICT ENERGY SYSTEM (DES)
BTU METER

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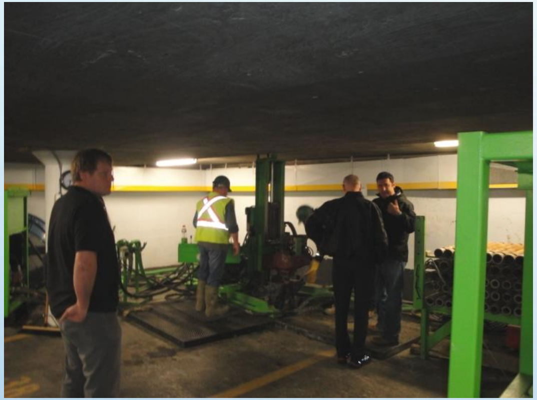
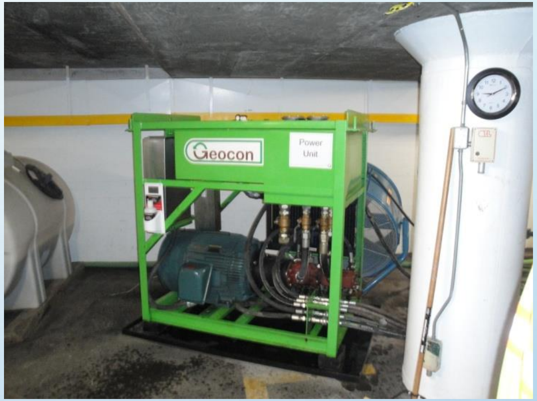
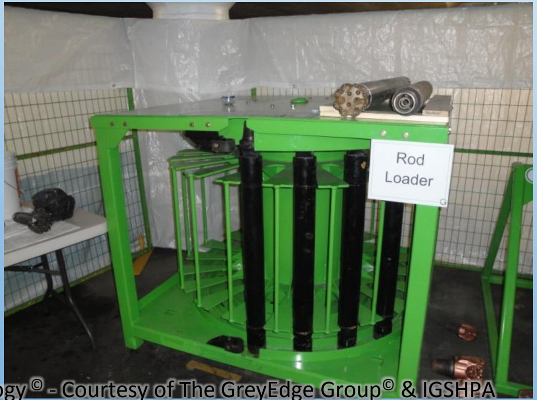
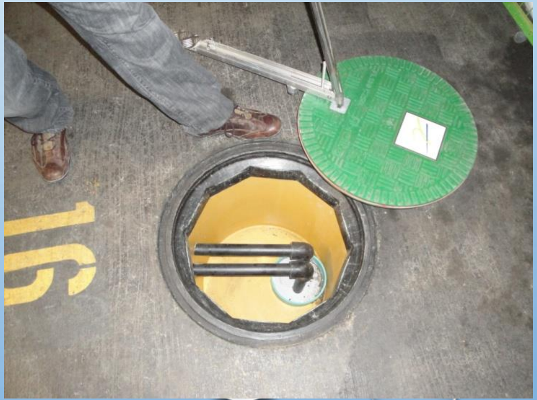
High-rise Drilling Technology

New realm of GX possibilities. High-rise and parking garage borefields with compact rigs that can drill to 600 feet or deeper.









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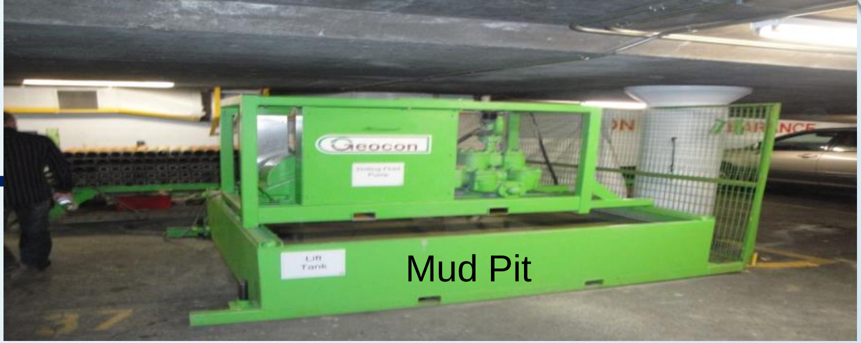
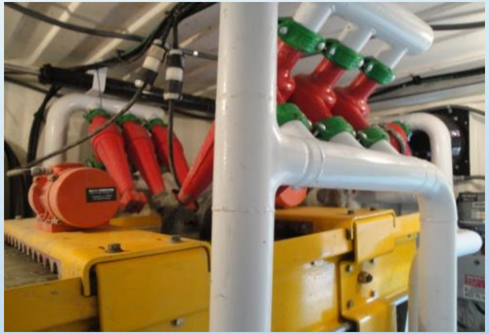
Solids Control and Cuttings Removal



Mud Pit

Surface Tank



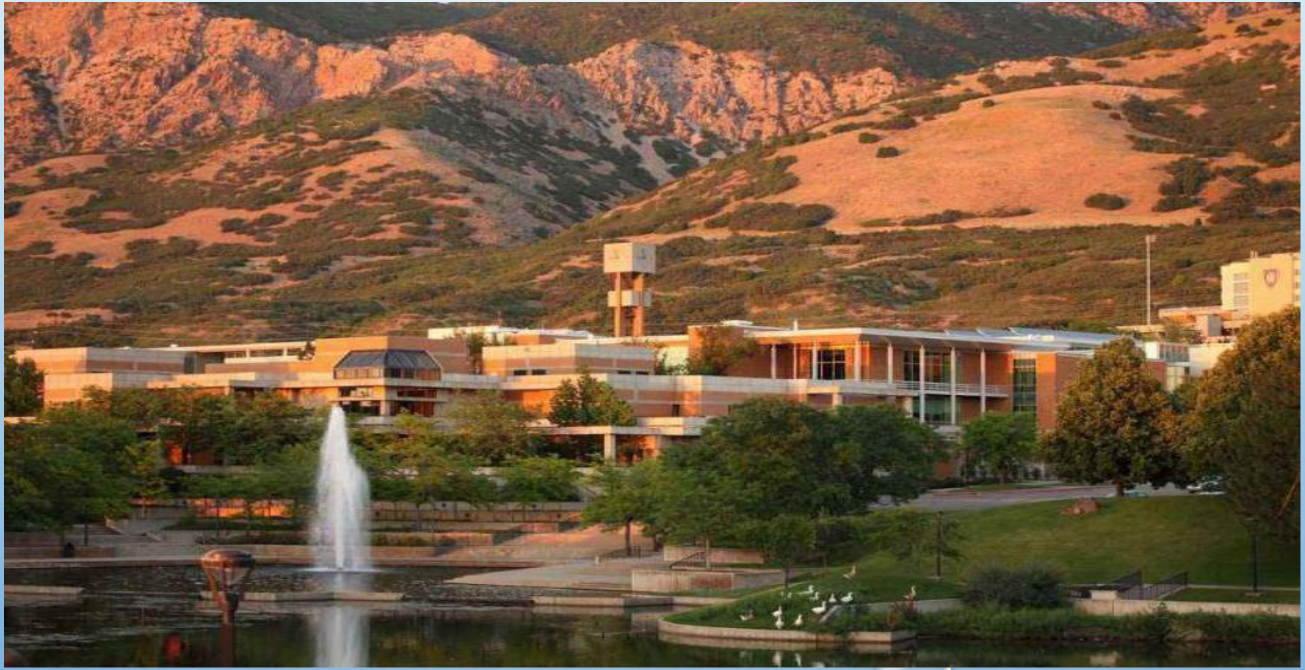
Hydro-Cyclone & Shaker

Dry Cuttings to Waste

Access to Waste

Powered by R-718 Technology

Ground Source Heat Pumps, Wasted Energy Recovery, and Reduced Water Consumption



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Step 5 {Chilled Water Conversion}

Discuss Transition from a Central Plant to a Thermal Highway using Chilled water loop.

Initially chilled water in the summer – as more buildings are retrofitted, less chiller time and more ambient loop time (Currently Oct 1 to May 1 AND WIDENING THE SEASON GAP)

    Retrofitted and new buildings supply ate tied into both the low temp side of the CWL and the return side of the CWL.
    With CWL, GX buildings draw from the RCWL (May through September)
    October through April – Chillers off, all ambient loop – (diversity is holding the ambient ~60 F)

Ambient Loop
Parallel _ old chilled water supply
Buildings tied to both sides of the parallel loop
Akin to reversing direction
Immediate and future advantage is: Choose building status from best source (Temperature)

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Thermal Highway© Master Plan

- Long term, ground source will supplement, then replace central plants
- Ground Source provides heating and cooling using existing chilled water lines
- Ground Source becomes thermal storage for the campus heating and cooling and to enable (hourly) load shifting

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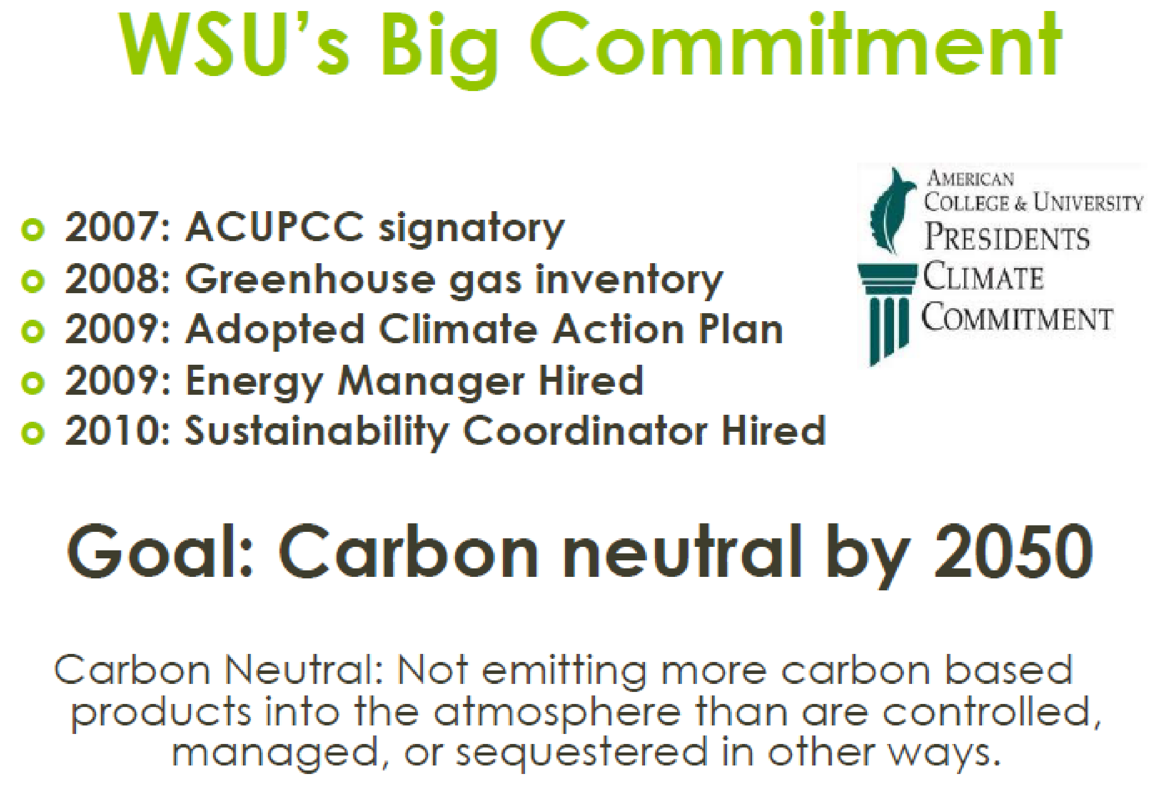


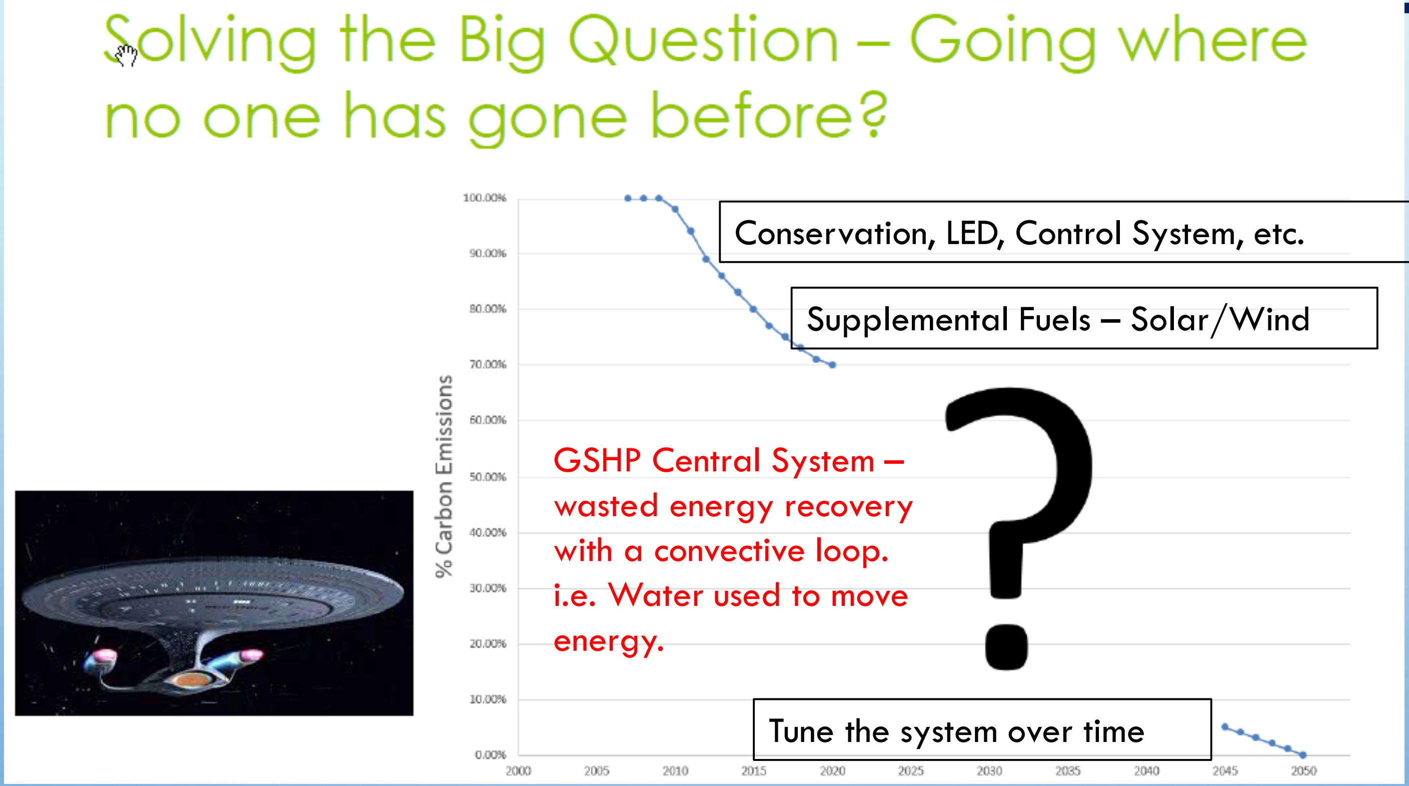
WSU's Big Commitment

- 2007: ACUPCC signatory
- 2008: Greenhouse gas inventory
- 2009: Adopted Climate Action Plan
- 2009: Energy Manager Hired
- 2010: Sustainability Coordinator Hired

Goal: Carbon neutral by 2050

Carbon Neutral: Not emitting more carbon based products into the atmosphere than are controlled, managed, or sequestered in other ways.

WHY THE NEW ATTENTION TO GROUND SOURCE HEAT PUMP SYSTEMS?



Solving the Big Question – Going where no one has gone before?

Conservation, LED, Control System, etc.

Supplemental Fuels – Solar/Wind

GSHP Central System – wasted energy recovery with a convective loop. i.e. Water used to move energy.

?

Tune the system over time

WSU Carbon Neutral by 2050

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Getting Started:

Thermal Highway©

Unique design concept: Transition into a ground coupled hybrid system by using the Chilled water distribution line.

Initially handle system heating and cooling with loopfield and building diversity in the heating season.

Reduce and/or shift load on towers by storing energy in the loopfield.

Limited heating and cooling in the shoulder months No system chillers.

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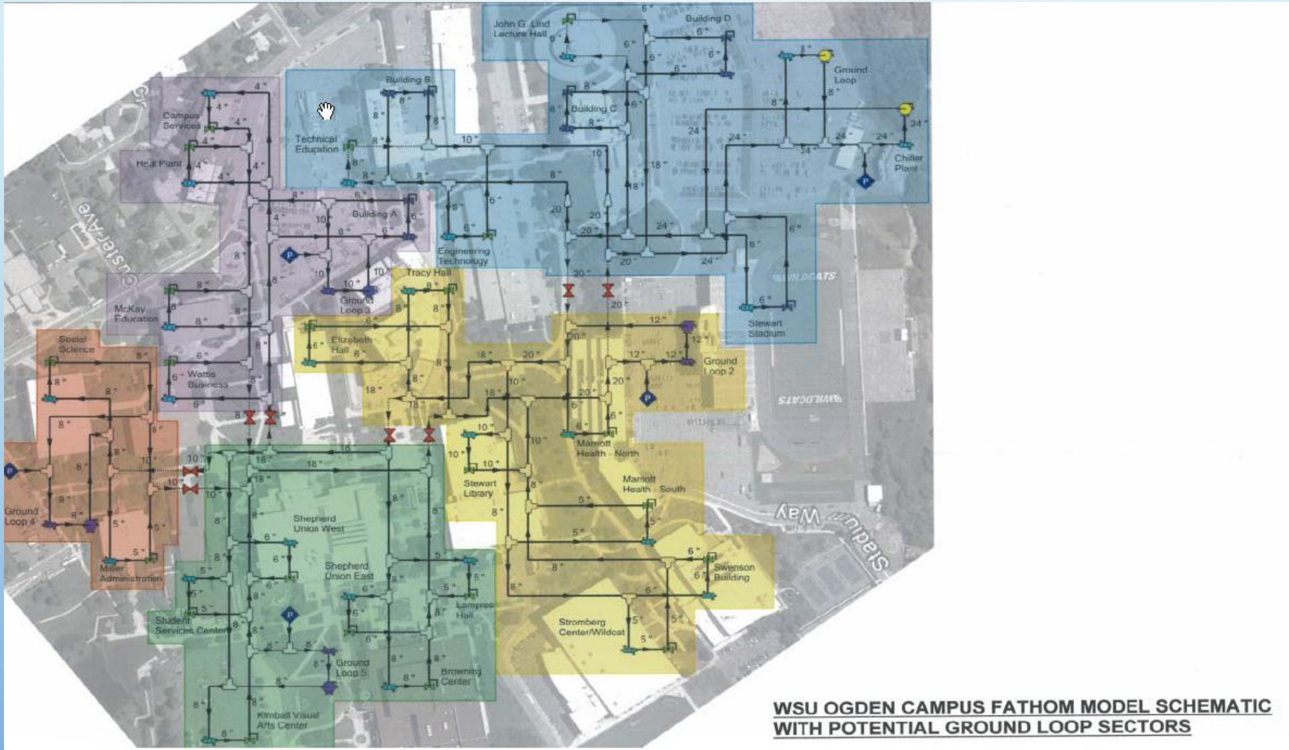
Existing Chilled Water piping (in tunnels)



WSU OGDEN CAMPUS FATHOM MODEL SCHEMATIC
WITH POTENTIAL GROUND LOOP SECTORS

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WSU Gets to Work!

Powered by R-718 Technology © - Courtesy of The GreyEdge Group©

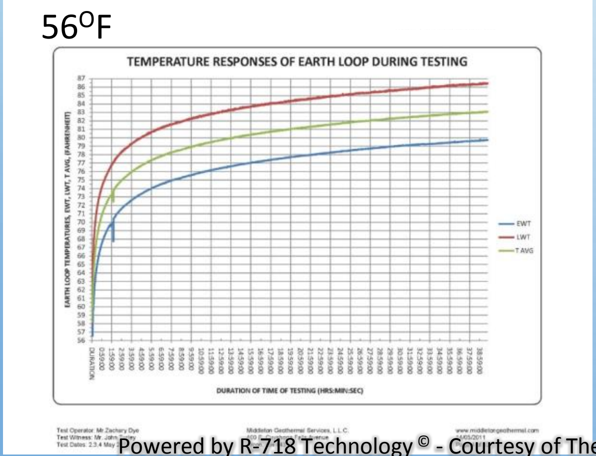
Getting Started:

Loopfield #1 & #2 – Testing and Economics

TC testing December 2013 & December 2016

TC – 1.71 Btu/hr-ft-^{O}F (W5) @ 56^{O}F

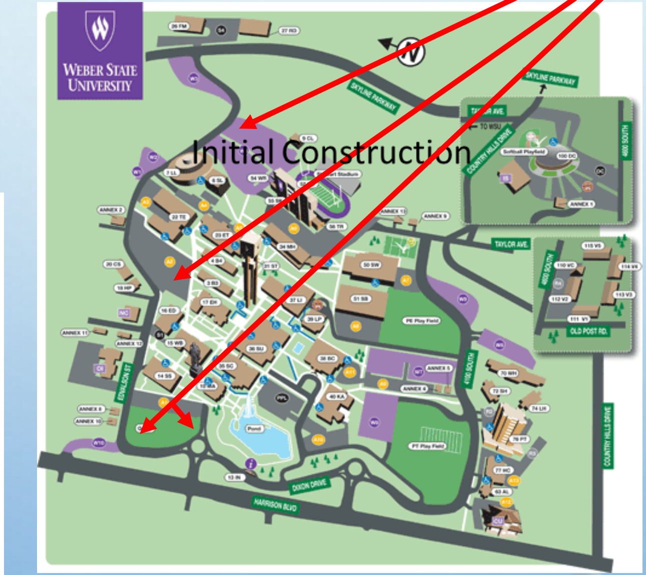
TC – 1.18 Btu/hr-ft-^{O}F (A-2) @ 56^{O}F



Test Operator: Mr Zachary Dye
Test Witness: Mr. John
Test Dates: 2,3,4 May

Middleton Geothermal Services, L.L.C.

www.middletongeothermal.com



#1 Begin Borefield Construction and capacity study Spring 2015.

#2 Begin flexible Borefield design Spring 2017. (Execution based on budget).

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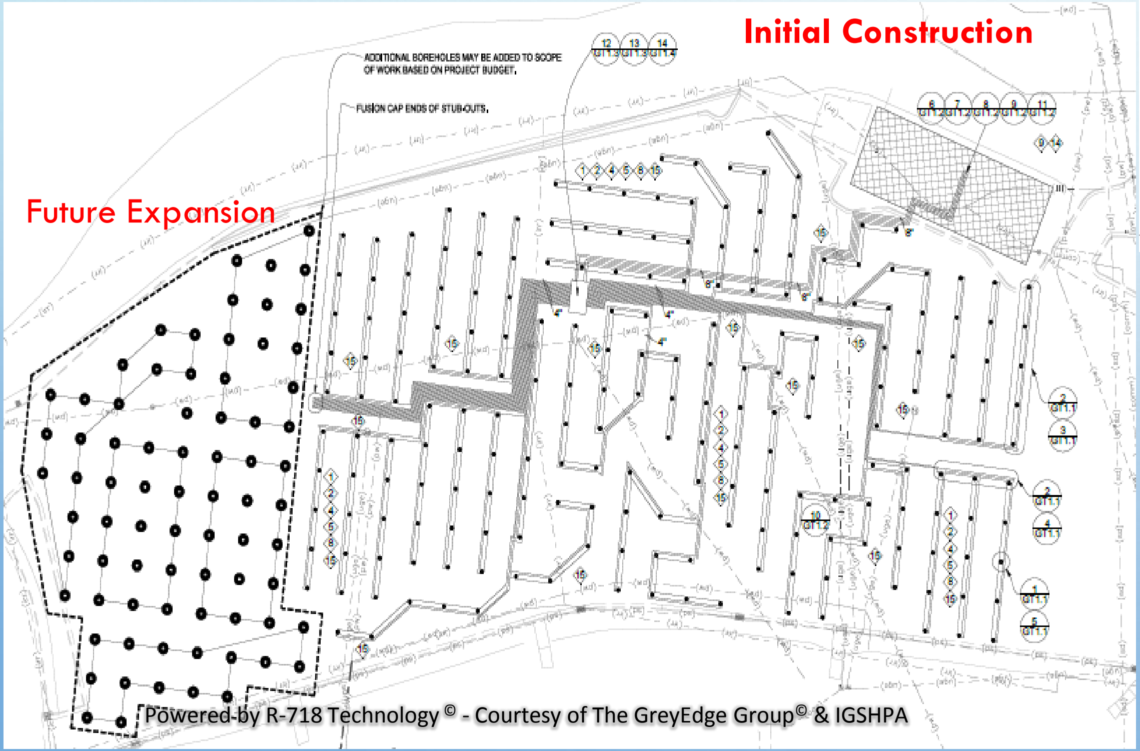
Getting Started:

Loopfield #1 – Construction


ADDITIONAL BOREHOLES MAY BE ADDED TO SCOPE OF WORK BASED ON PROJECT BUDGET.
FUSION CAP ENDS OF STUB-OUTS.

Initial Construction

Future Expansion

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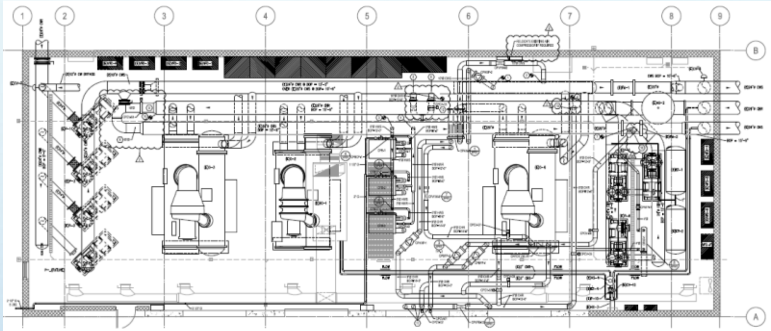

Getting Started:

Loopfield #1 – Statistics

Size of Initial Field:
2 – fields 210 boreholes ~ 273' deep
57,857 vertical feet
~300 to 350 tons direct Use
~400 tons dynamic use

Approximate Thermal Storage (Short term)
Fluid – 640 Ton-hours
Grout – 700 Ton-hours
Formation – 1,055 Ton-hours
2,395 Ton-hours

Size of Initial Field:
1 – field 150 boreholes ~ 425' deep
63,750 vertical feet
~300 to 400 tons direct Use
~500 tons dynamic use

Approximate Thermal Storage (Short term)
Fluid – 540 Ton-hours
Grout – 875 Ton-hours
Formation – 1,655 Ton-hours
2,540 Ton-hours

In a hybrid distributed energy system, the field becomes a thermal battery enabling load shifting.

Total thermal storage to date:
4,935 Ton hours

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WEBER STATE UNIVERSITY

Finished Building
First full year:

EUI 25

(Heating by field and Thermal Highway – replacing NG)

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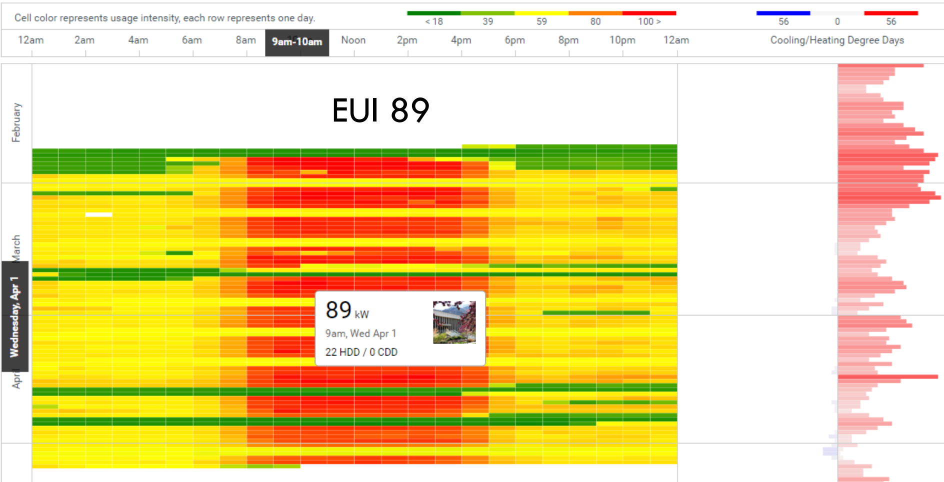
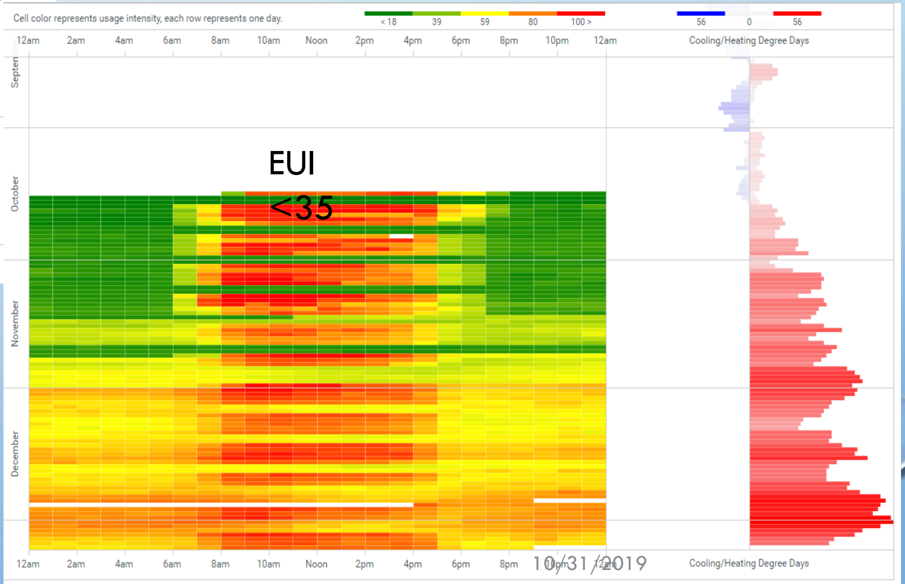
WSU Initial Economic Results
~39% of Normal

Energy Intensity for one 400,000 sq. ft. Section – RED Area is mid-day-energy concentration.



EUI 89

Before Heat Pumps
and Central System



EUI
<35

After

Before: Central Plant fuel costs:
$12,800 per month (January).

After: Start-up of Central Loop
System fuel costs: $2,700/month
(January).

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Lohrenzian Economic Calculations:

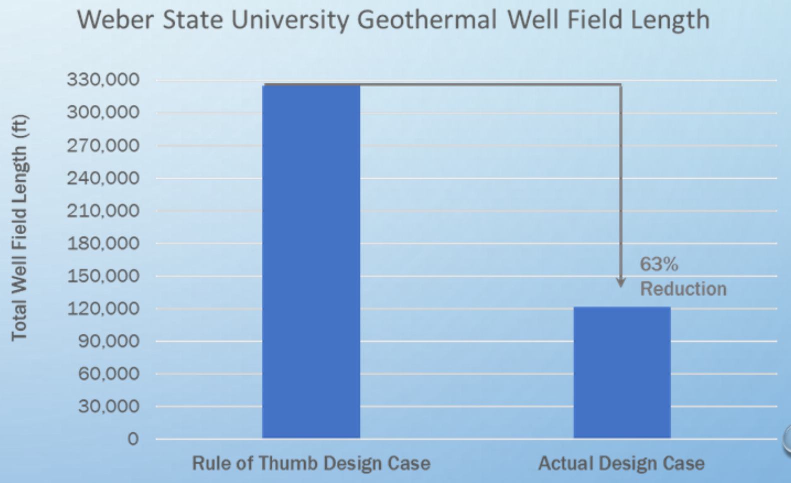
- Total GX -121,607 Vertical Feet of GX in two fields
- Approximately 650,000^2ft = ~1,625 tons
- 608 tons of loop or 37% GEO vs 325,000 vertical feet for independent buildings.

AVOIDED VERTICAL LOOP
Capital cost reduction @ ~ $16.25/vertical foot
325,00 x $16.25=$5,687,500
OR 121,607 x $16.25=$1,976,114

CAPITAL SAVINGS OF: ($3,711,386)

AND

OPERATING UTILITY SAVING of
$1,984,280.33



ROI of existing field due to use of Thermal Highway: < 1 year

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Result and Rewards

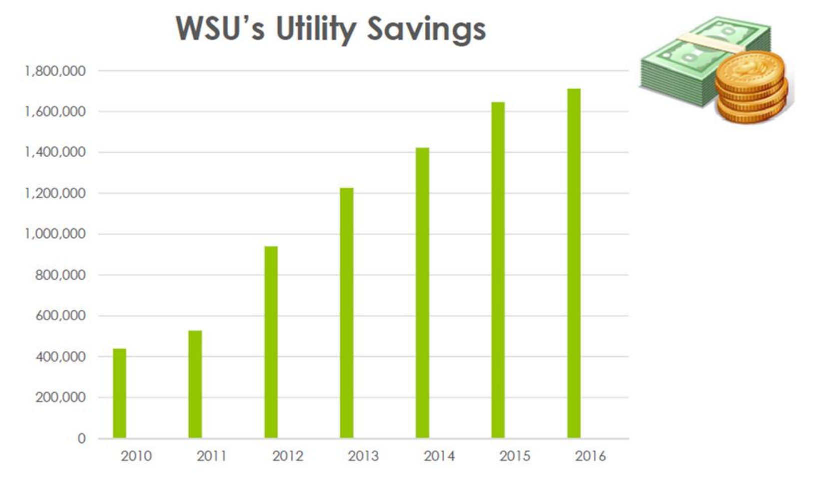
Direct greenhouse gas emissions reduced by 31% since the baseline year of 2007

(Even with the addition of 375,210 s.f. – (~15% increase)

Electricity Consumption down by 29%

Natural gas consumption down by 33%

Energy cost down ~40%



Heat Pumps, Energy, WER, and Water

COLORADO MESA
UNIVERSITY

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Step 7 {True Energy Highway – One-Pipe Loops}

Discuss the difference between a Chilled water loop and a Thermal Highway using a One-pipe system for distribution

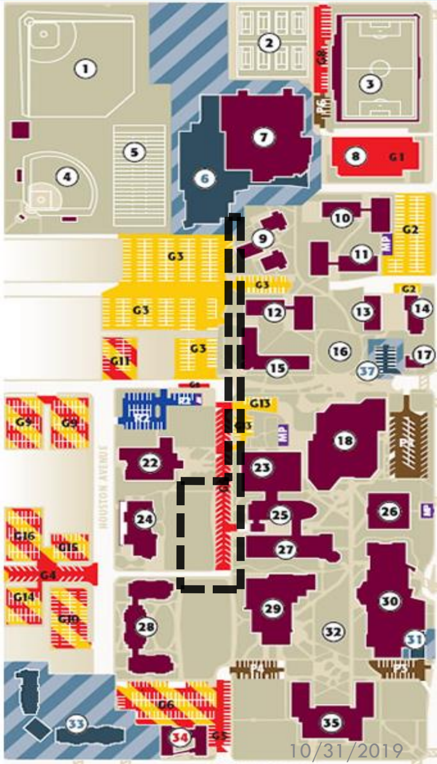
- No central plant equipment
- Multiple Central pumping stations enabling segregation of loop sections
- Loop becomes “Utility grade” because of the ability to bypass or include sections or buildings (independent function). This is an advanced level of design and implementation
- Ambient loop temperature is the primary central loop control
- Δ Temperature across the ambient loop controlls pump speed
- Fluid path is changed through a “distribution manifold” located in the central loop piping
- Global demand limiting

Ambient loop all year long 60 F to 90 F.

Mesa State College to Colorado Mesa University:

A central loop project was begun.

Step 1 – 1500 tons 450,000 ft^2.



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Vision for Expansion

SGT proposed a modular "Central Loop" approach that could grow with the campus.

Backbone is an 18" HDPE single pipe system

Distributed mechanical rooms provide redundant pumping.

HDPE pipeline connects Buildings, borefields, and all other hybrid components.

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Rapid Growth → Innovative Planning - 2019

Initial System called for 120,000 vertical feet

Current Installed Geothermal Loop – 171,000 vt. Ft.

2016 GX add – 36 boreholes, 600 feet deep – 21,600 vt. ft. 192,600 vt.ft.

Design Tonnage in 2007 - 2,200 tons

Design Tonnage in 2019 – 4,400 tons

Present Peak Load – 2,227 tons heating, 2,500 tons cooling

Current Cooling tower Capacity – 750 tons

Add 250 tons of existing CT capacity to the system

AND **add 400 tons passive cooling** from the irrigation system (April 1 through October 31)

Keep existing boilers ~900 tons

The boilers have not fired for 11 years to support the Central Loop

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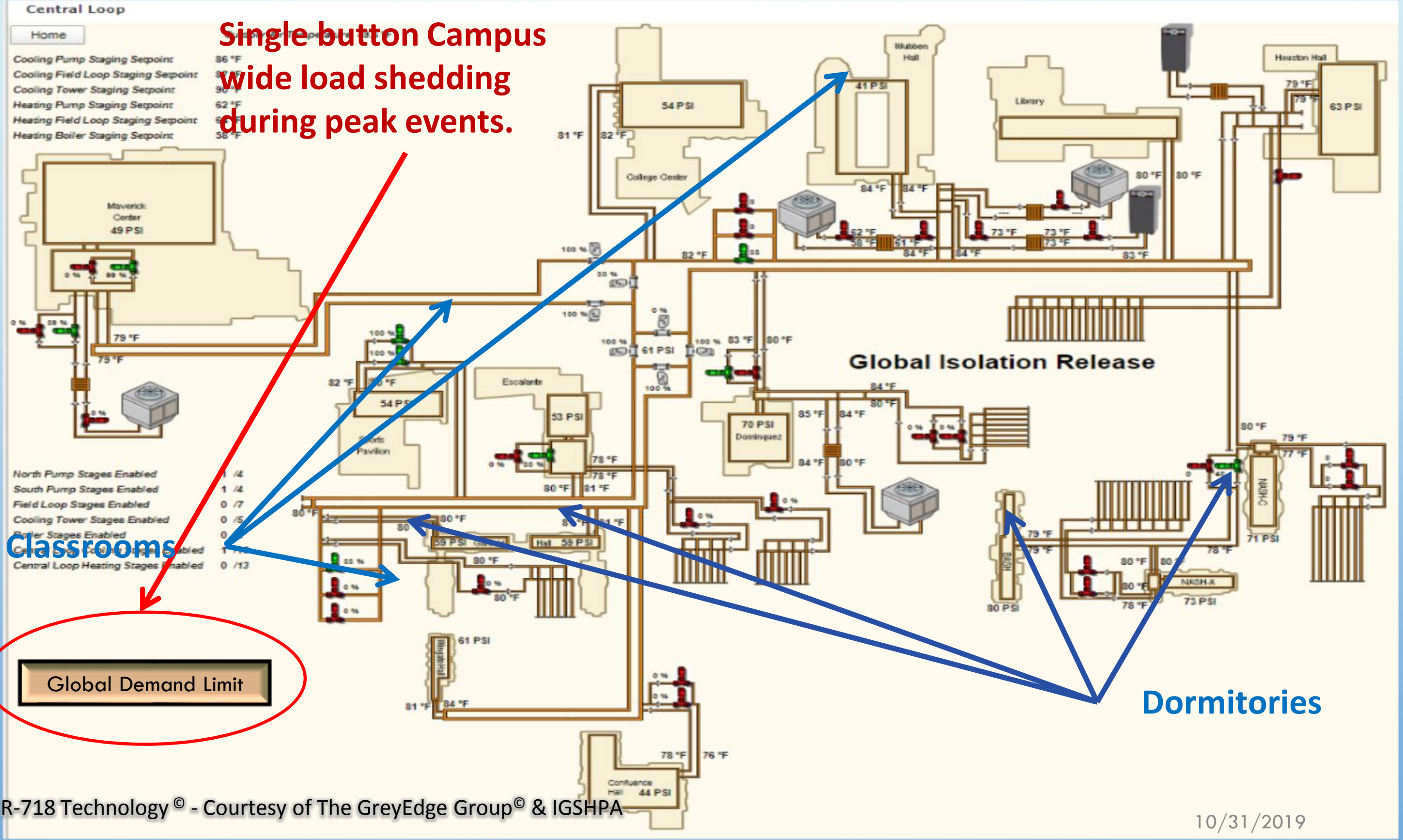
CMU'S CENTRAL LOOP & GMS



Cooling Pump Staging Setpoint 86 °F
Cooling Field Loop Staging Setpoint
Cooling Tower Staging Setpoint 90 °F
Heating Pump Staging Setpoint 62 °F
Heating Field Loop Staging Setpoint
Heating Boiler Staging Setpoint 58 °F

North Pump Stages Enabled 1 /4
South Pump Stages Enabled 1 /4
Field Loop Stages Enabled 0 /7
Cooling Tower Stages Enabled 0 /5
Boiler Stages Enabled 0
Central Loop Cooling Stages Enabled 1
Central Loop Heating Stages Enabled 0 /13

Single button Campus wide load shedding during peak events.

Classrooms

Dormitories

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Operational Experience

Goal: Optimize energy costs and minimize water use.

Shift load, store energy in the borefield and shed energy at night with the tower.

SHORT TERM BOREFIELD THERMAL STORAGE

- DEEP EARTH TEMPERATURE 62° F, FORMATION TC 1.24 BTU/HR-FT-°F

SYSTEM CAPACITY AT A FIELD TEMPERATURE INCREASE TO 85° F

- LOOPFIELD AND BUILDING FLUID - 2,654 TON HOURS
- THERMAL GROUT 5.25" BOREHOLE WITH TC 1.2 GROUT - 2,150 TON HOURS
- 2" OF BOREHOLE – 3,400 TON HOURS

~8,200 TON-HOURS TES

NIGHT SHEDDING WITH 750 TONS OF EQUIPMENT RUN FOR 4 HOURS:

~2,900 TON HOURS –

FIELD TEMPERATURE 75° F

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System Water Savings

Goal: Optimize energy savings and minimize water use.

Strategy #2: Reduce cooling tower water and reduce electric load.

WITHOUT DISTRICT SYSTEM:

- TOWERS REQUIRED ~ 3,400 TONS (NOMINAL PLUS CT ENERGY)
- CALCULATED WATER USE: 14.5MM GALLONS/YR. (2,400 EFLRH)
- ***LOAD 784 KW***

WITH DISTRICT SYSTEM:

- EXISTING SYSTEM: 750 TONS
- ESTIMATED WATER USE: 4.5MM GALLONS/YR. (2,400 EFLRH)
- ***LOAD: 185 KW***
- REDUCE OR ELIMINATE COMBUSTION FOR HEATING AND DOMESTIC HOT WATER.

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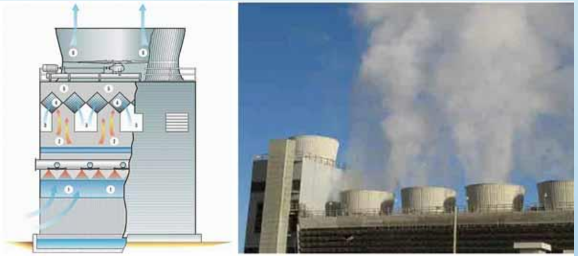
GX Heat Pumps, WER, and Water

__At The Power Plant__



- 41% of U.S. fresh water use is power plant cooling (USGS)
- Reductions in **SITE** electric consumption reduce power plant cooling water.

__On Site__

- 1/3 of site water is often consumed by the cooling tower(s)

  FYI: In our climate a small high school will consume 600 gallons per hour when the tower is running.
- Hybrid systems can reduce cooling water by 70%
- Balanced WER / GSHP-thermal storage systems can eliminate cooling tower water consumption.

Operational Experience

Goal: Optimize energy costs and minimize water use.

Strategy #3: Shift load, store energy in the borefield and shed energy at night with the tower.

SHORT TERM BOREFIELD THERMAL STORAGE

- DEEP EARTH TEMPERATURE 62 °F, FORMATION TC 1.24 BTU/HR-FT-°F
- FORMATION THERMAL DIFFUSIVITY » 0.90 FT^2/DAY

SYSTEM CAPACITY AT A FIELD TEMPERATURE INCREASE TO 85° F

- LOOPFIELD AND BUILDING FLUID - 2,654 TON HOURS
- THERMAL GROUT 5.25” BOREHOLE WITH TC 1.2 GROUT - 2,150 TON HOURS
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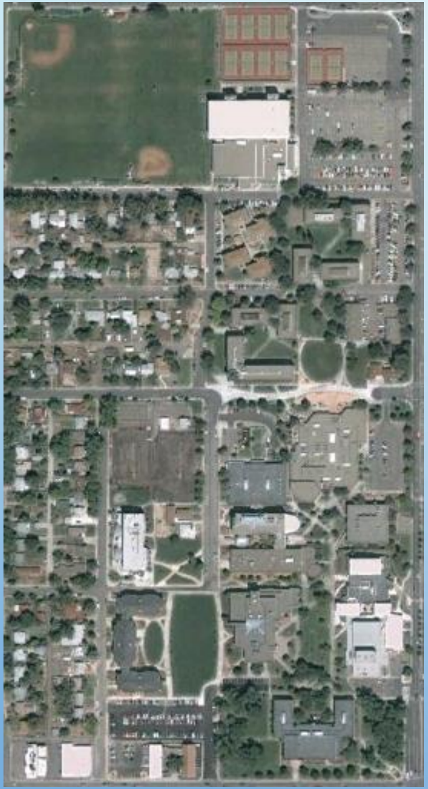
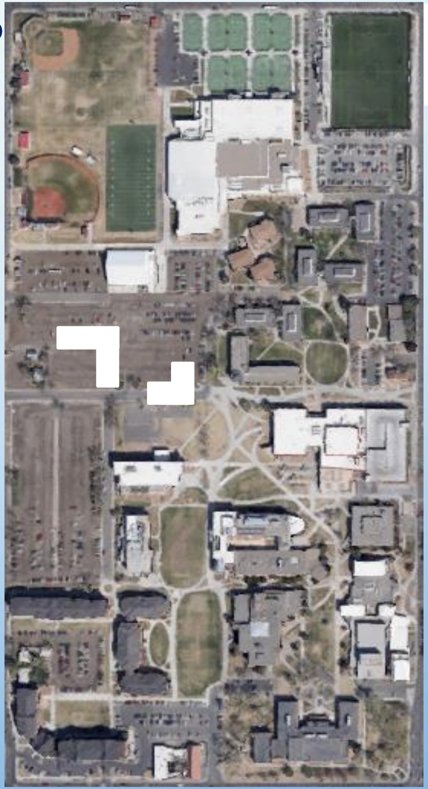
Rapid Growth → Innovative Planning



MESA STATE COLLEGE

2006

- 3,500 Students
- ~6 City Blocks
- 6 major new complexes or renovations planned in 5 years
- Installed first stand-alone Geo system.



COLORADO MESA UNIVERSITY

2019

- 11,500 Students
- ~12 City Blocks
- District Energy Sys. Connects 16 buildings, 5 loopfields
- Expansion of campus District Energy System continues

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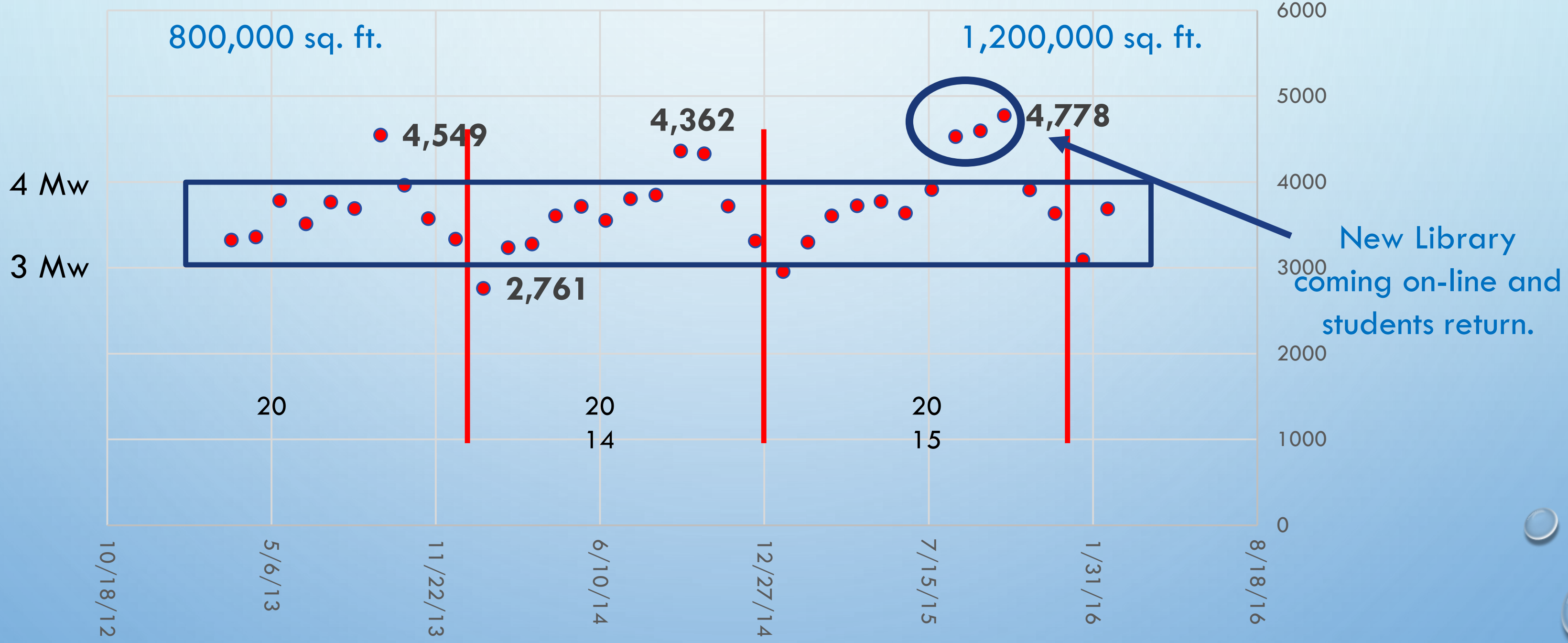
Colorado Mesa University
Monthly Peak kW (Power) 2013 - 2016



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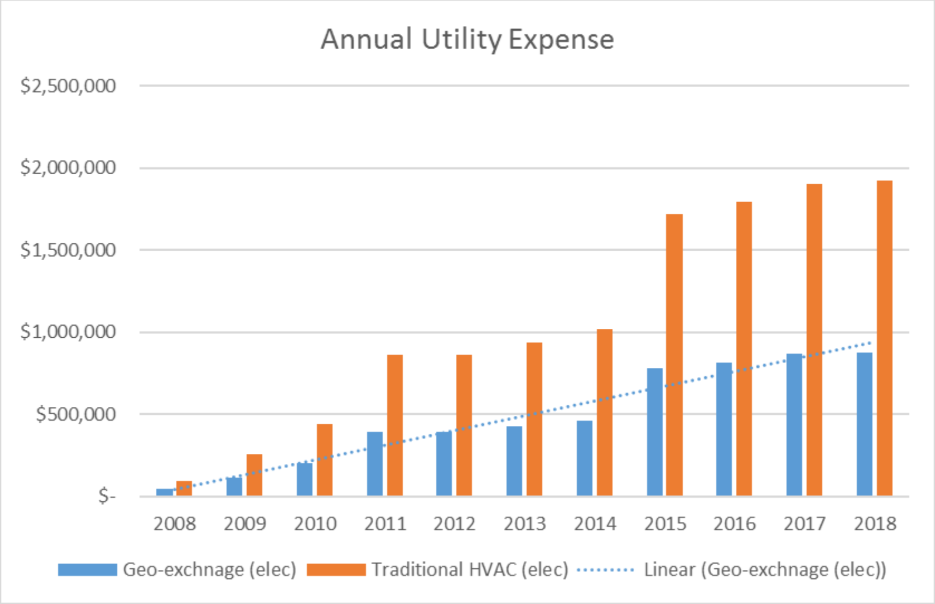
HOW IT SAVES MONEY AND ENERGY

- Provides up to 89% of the energy needed to heat and cool connected buildings (1,167,606 sf)
- Results in energy savings in excess of $1,050,845 / year.



Total System Cost after Utility and State Rebates: $ 8,243,829.25

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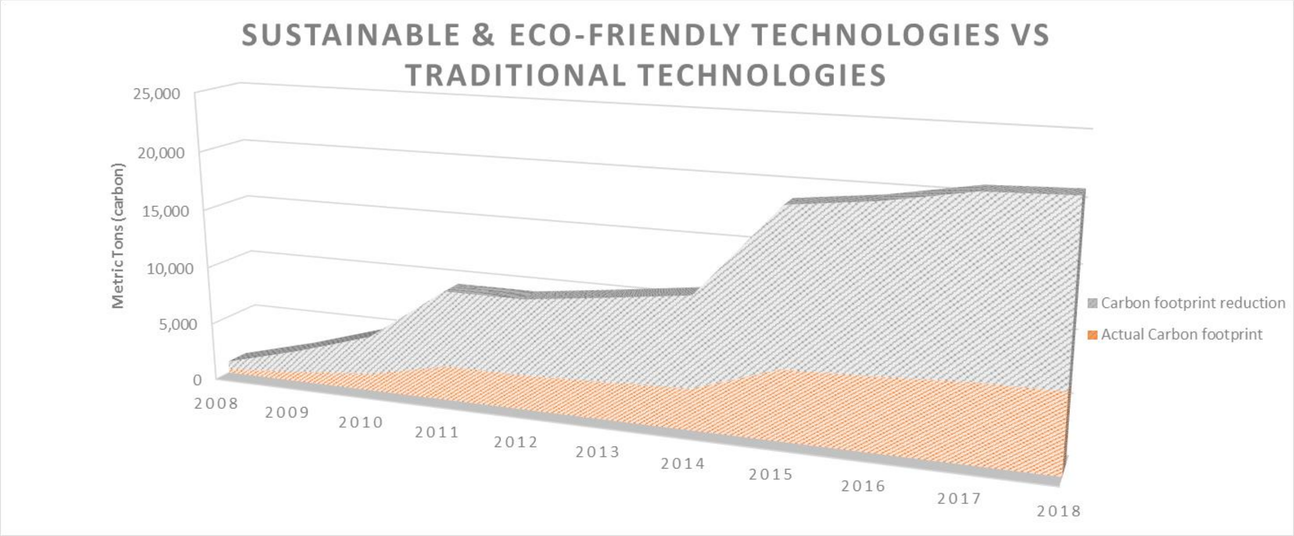
CARBON FOOTPRINT REDUCTION

Carbon footprint has been reduced by 7,881 metric tons/yr.



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In refrigeration technology, water (H_2O) is referred to as R718 because of its molar mass of approx. 18 g/mol.

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Questions?

Comfot from the ground up

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GWACHEON NATIONAL SCIENCE MUSEUM, SEOUL, KOREA

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LUNCH !!!

The HEET Grid Game

Conversation Starter: Your First Job?